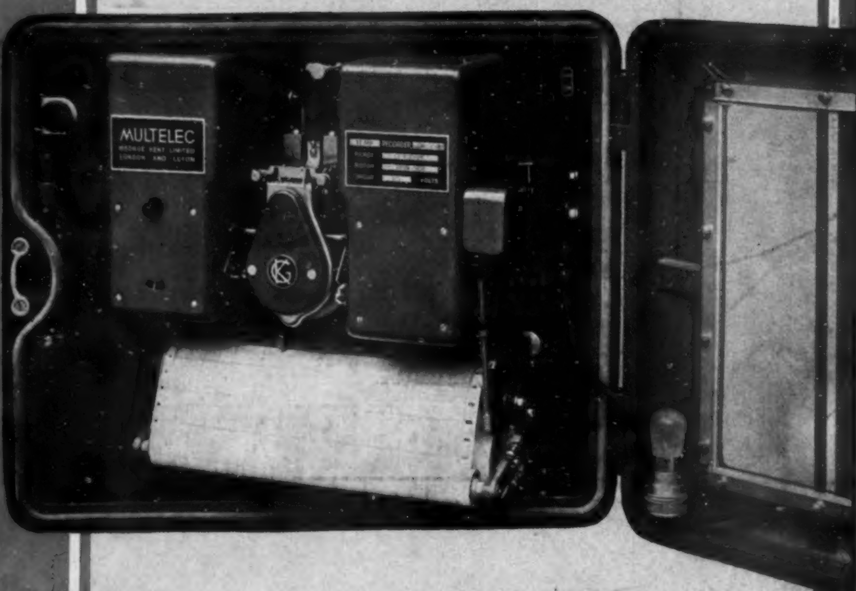
INSTITUTE OF METALS: SHEFFIELD MEETING | IRON AND STEEL INSTITUTE: MIDDLESBROUGH MEETING | ENGINEERING AND MARINE EXHIBITION AT OLYMPIA

METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 16. No. 95. SEPTEMBER, 1937. Price 2/-. [Subscription 24/- per annum post free.]



THE MULTELEC

The Kent Multelec, sensitive and powerful, lends itself to application in very many branches of engineering, particularly for temperature control. It follows the Kent traditions of fine design and workmanship, and is manufactured at Luton in the specially equipped factory built expressly for the Multelec. Many warm tributes have already been received in testimony of the fine service given by this instrument in a variety of important uses.

With the great accuracy of the Multelec, owing to the basic principle employed, is coupled reliability, extremely robust construction, and an ample reserve of relay power. By way of example, 1/1000th inch of galvanometer deflection is instantly detected and recorded, while the relay action is so powerful that it cannot be restrained by hand.

Equally important are the specially developed Kent primary elements, which are of the same high standard of sturdiness and sensitivity.

OTHER OUTSTANDING FEATURES

Potentiometric principle, ensuring high accuracy, due to independence of changing galvanometer characteristics and indifference to high and varying line resistance : perfect automatic temperature compensation : frequent automatic current standardising, checking accuracy at hourly intervals throughout the day : extra robust galvanometer : high frequency measuring cycle, ensuring immediate recording of any change : ample width of chart (10 inches) : special design permitting control units to be easily added : British manufacture throughout.

GEORGE KENT LTD., LUTON, BEDFORDSHIRE
LONDON OFFICE - 200 HIGH HOLBORN, W.C. I.

FOR TEMPERATURE CONTROL

The Kent Multelec, as a recording and controlling pyrometer, deals with temperatures ranging from minus 300°F. to plus 3,000°F., a change being detected by the recorder within two seconds of its occurrence. Multipoint recorders with distinctive chart readings are made for any number of points up to six, and also for twelve points.

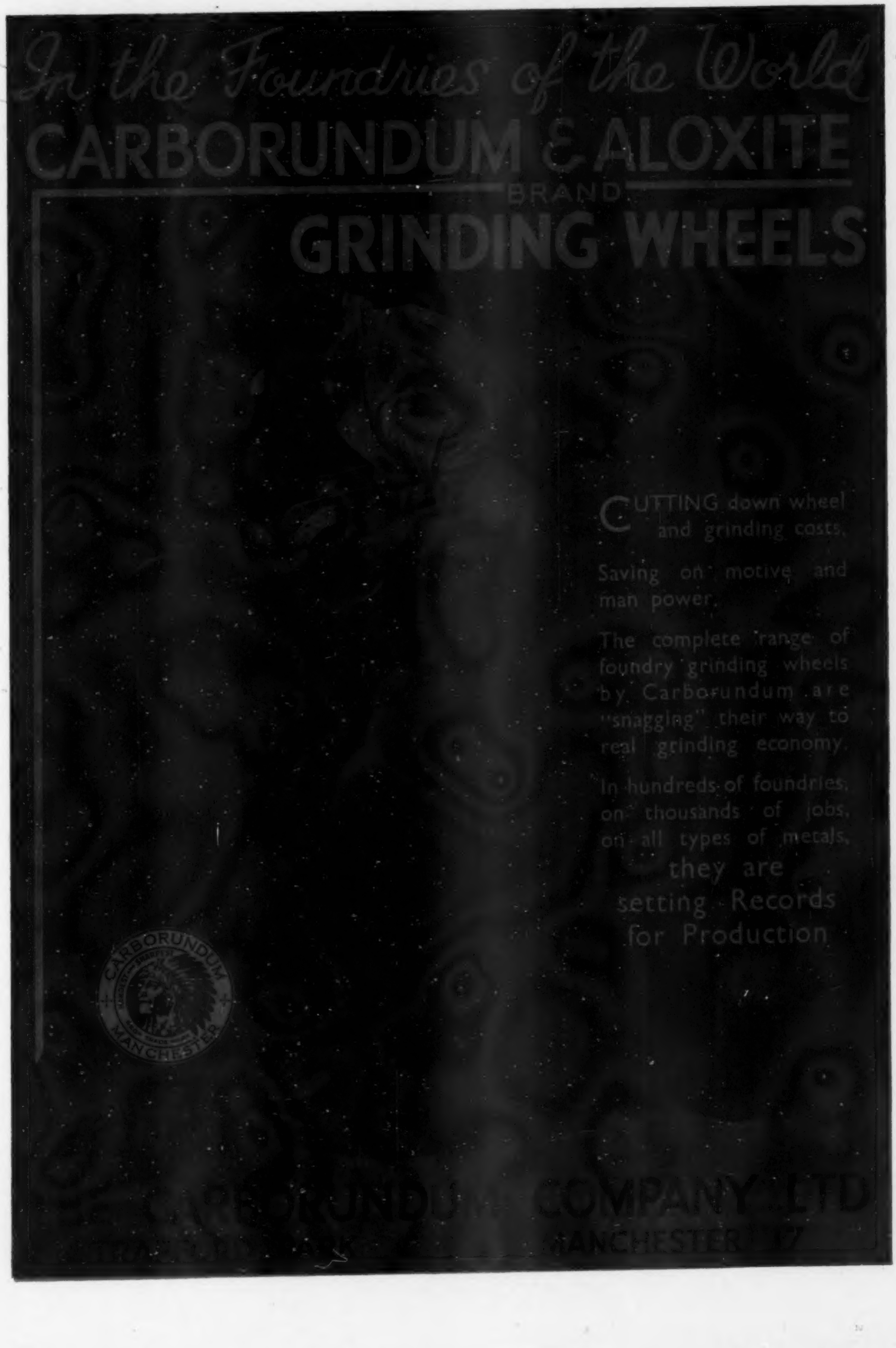
The Kent Multelec Recorder-Controller is being used in steelworks, oil refineries, sugar refineries, food factories, and in connection with heat treatment in many industries.

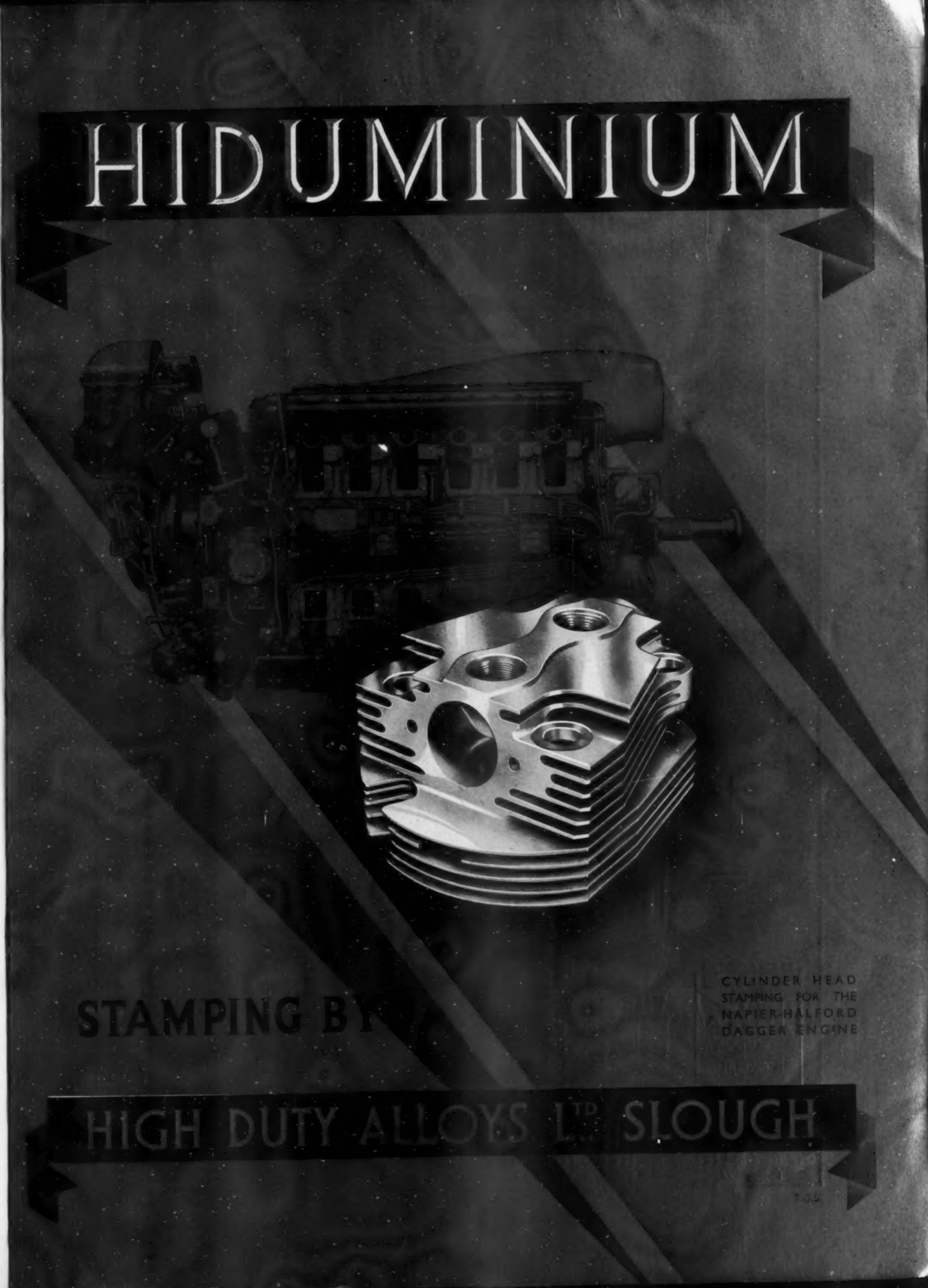
FOR pH AND ELECTROLYTIC CONDUCTIVITY

The Multelec is being used for control in the following :—

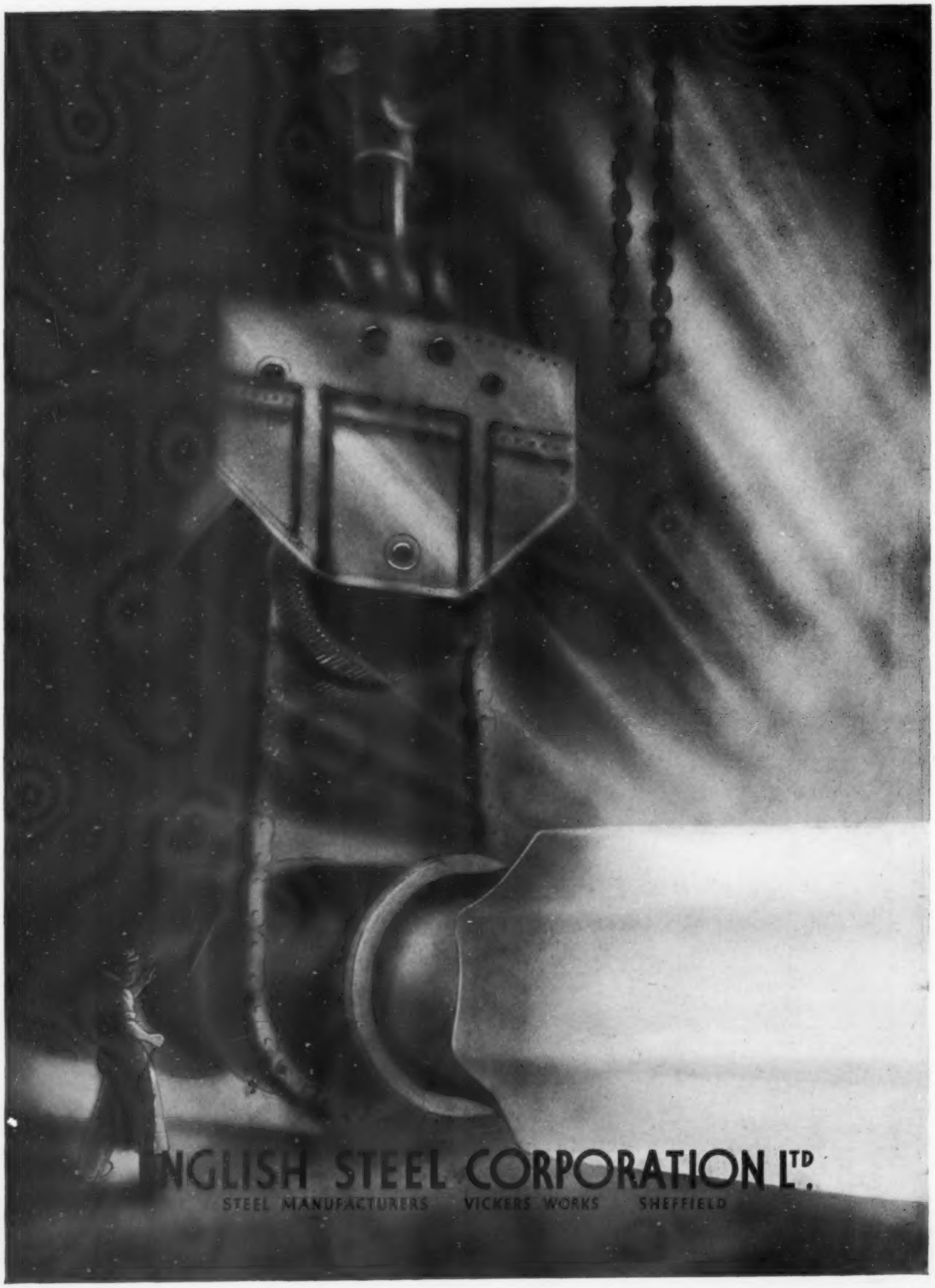
Waterworks : chemical treatment.
Sewage works : chemical treatment.
Power stations : gas washing and conditioning of feed water.
Chemical manufacture : process control.
Paper Mills : alum control.
Food factories : various processes.
Sugar mills and refineries : control of sulphitation and carbonatation, also pan boiling.
Textile mills : water conditioning, mercerizing and caustic baths.
Mining : oil flotation.
Nickel plating : bath control.
Oil refineries: anti-corrosion treatment.
The neutralisation of trade effluents.

GEORGE KENT


In the Foundries of the World
CARBORUNDUM & ALOXITE
BRAND
GRINDING WHEELS
CUTTING down wheel and grinding costs.
Saving on motive and man power.
The complete range of foundry grinding wheels by Carborundum are "snagging" their way to real grinding economy.
In hundreds of foundries, on thousands of jobs, on all types of metals,
they are setting Records for Production
CARBORUNDUM
MANCHESTER
COMPANY LTD
MANCHESTER


HIDUMINIUM
STAMPING BY
CYLINDER HEAD STAMPING FOR THE NAPIER-HALFORD DAGGER ENGINE
HIGH DUTY ALLOYS L^{TD} SLOUGH


Free Machining
ALUMINIUM
ALLOY
N. A. 28S.


ENGLISH STEEL CORPORATION LTD.
STEEL MANUFACTURERS VICKERS WORKS SHEFFIELD

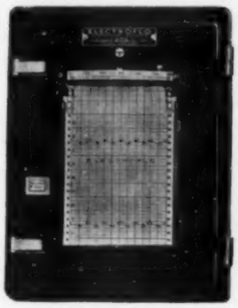
RELIABLE

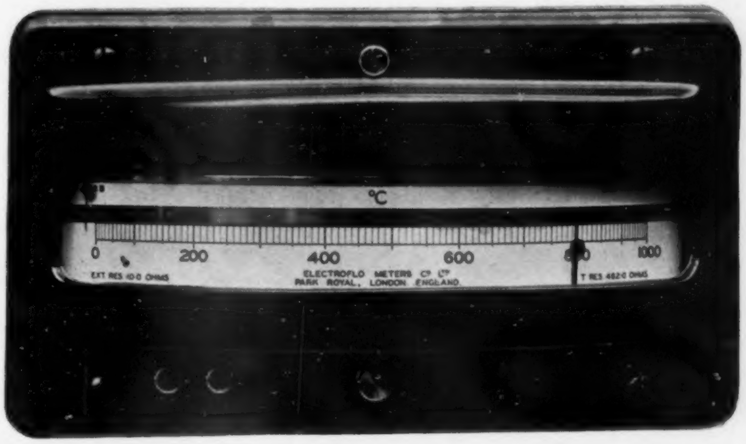
The best that can be said of a pyrometer is that it is *reliable*. "Attractive features" are no compensation for expensive "let downs," spoiled work and damaged furnaces.

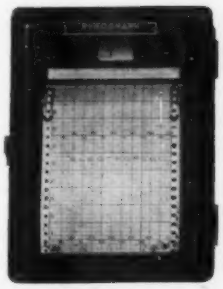
Reliability is fundamental, and can be ensured only by basically-sound design and first-quality materials and workmanship. The trouble-free service and maintained accuracy of Electroflo pyrometers have earned them the unqualified approval of every prominent furnace builder and innumerable pyrometer users.

Right. 10" Scale Indicating Control Pyrometer, a superior model of the *original* mechanically-operated mercury-switch control pyrometer

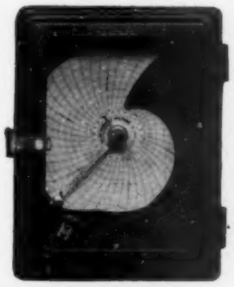
Below. A.C. Synchronous motor-driven Single or Multi-point Recording Pyrometer for up to six records, with 6" wide, 1,600 hour roll chart.



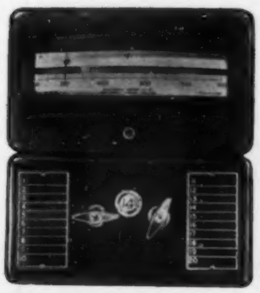




"Pyrograph" Temperature Recorder—single or two record—with spring-wound clock driven, 6" wide 1,600-hour roll chart.



Programme Controller for use with Electroflo Control Pyrometers with specially cut cams to maintain any desired time/temperature cycle.



Single or Multipoint Indicating Pyrometer with totally-enclosed double-pole rotary switch and automatic station indicator.

★ Interested Metallurgists and Plant Engineers are invited to write for fully descriptive catalogues and interesting articles on Automatic Furnace Temperature & Atmosphere Control.

ELECTROFLO PYROMETERS

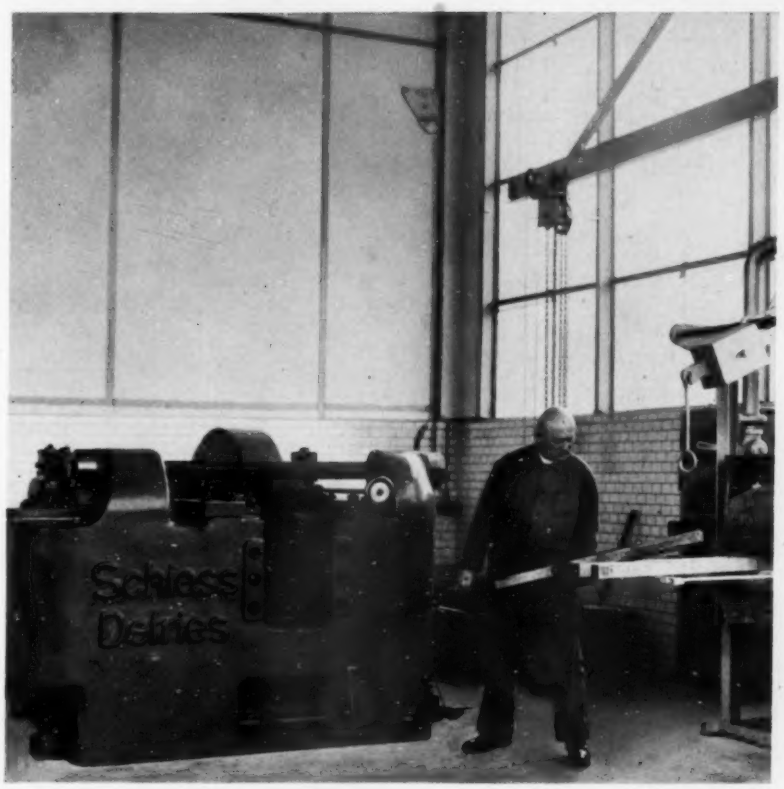
INDICATING ★ RECORDING ★ CONTROLLING

MAKERS OF THE ORIGINAL MECHANICALLY OPERATED MERCURY-SWITCH CONTROL PYROMETER

Advert. of:—ELECTROFLO METERS COMPANY LTD., ABBEY ROAD, PARK ROYAL, LONDON, N.W.10

Forged - **FROM THE BAR**

without loss of material



6328

215 m/m = $8\frac{1}{2}$ in.
70 m/m = $2\frac{3}{4}$ in.
125 m/m = $4\frac{15}{16}$ in.
45 m/m = $1\frac{3}{4}$ in.

Vast savings in material and rapid, economical production of forged parts, by using our

HORIZONTAL FORGING MACHINES

9 Models with maximum final pressure ranging from 50 to 2,000 tons. Due to the great strength and absolute inflexibility of these machines, correct dimensioning of the dies, favourable working speed and large power reserve—perfectly formed workpieces requiring only very slight dressing are regularly obtained in the fewest possible operations and heats.

Schiess-Defries A.-G. Düsseldorf

also **Schiess-Defries (Gt. Britain) Ltd., 25, Victoria Street, London, S.W. I.**

Agents : Egypt—Société Commercial Belgo-Egyptienne, Cairo, P.O.B. 127; No. 18, Rue Maghraby. **South Africa**—Fraser & Chalmers (S.A.), Ltd., P.O.B. 619, Johannesburg. **India**—J. O'Hara Murray & Co., 100, Clive Street, Calcutta, **Japan**—L. Leybold Shokwan A-G., Tokyo, Nihonbashiku Tokyo Tatemono Building. **China**—Siemssen & Co., Mach. Tool Department, Shanghai, 451, Kianzse Road. **South America**—Brazil—Dr. H. Lange, Rio de Janeiro, Rua dos Benedictinos, 15/17-1,°. **Chile**—H. Wulff, Santiago de Chile, Casilla, 2109. **U.S.A.**—Ulrich Kauermann, Fountain Square Buildings, Cincinnati, Ohio.

MAXHETE
HEAT-RESISTING STEELS

In the early days practically only one analysis of specifically heat-resisting steel was known; but since then the varying requirements of engineers and steel users have led to the production of at least six steels, each of which is suitable, in varying degree, for parts and purposes requiring extreme heat-resistance combined with a measure of mechanical strength under heat.

The following notes summarise those steels of heat-resisting character made by Edgar Allen & Co., Ltd. A table shows the safe working load that can be applied to each of these steels at specific temperatures, and a further table shows the coefficient of expansion per degree C. of each steel.

Edgar Allen & Co., Ltd., will be glad to amplify any of this information, if desired, and to advise as to the suitability of any of these steels for a specific purpose.

Maxilvry A.W.P.

(Austenitic nickel-chromium steel).

Whilst this steel was primarily developed on account of its corrosive-resisting properties and of its resistance to intergranular attack, it has definite non-scaling properties and high strength values at temperatures up to 800° C. Used extensively in the chemical trade for pots, retorts, etc. It can be supplied in the form of bars, sheets, forgings, or castings.

Maxhete 1A.

(Austenitic nickel-chromium-tungsten steel).

This steel has resistance to scaling and intergranular attack and high strength values at temperatures up to 900° C. Used extensively for parts subject to heat up to 950° C. and at the same time requiring adequate strength. It has been used very successfully for valves for internal combustion engines, owing to the fact that it does not air harden and always maintains a high impact value. It can be supplied in the form of bars or forgings.

Maxhete No. 2.

(Austenitic high chromium-nickel steel).

Can be used where great resistance to scaling is desired at temperatures up to 1050° C. Also has good strength values at elevated temperatures, although not as good as those obtained with Maxhete No. 4. Owing to the high chromium content it is better adapted to resist gas containing an appreciable amount of sulphur in one form or another. It can be supplied in the form of bars, sheets, forgings or castings, and can be fully recommended as a general steel for parts subject to heat.

Maxhete No. 3.

(High chromium steel).

This steel was designed primarily for rabble arms and rabble blades in roasting furnaces. Has great resistance to corrosion and scaling even against gases containing sulphur in various forms. Can be well recommended where the temperature is more or less constant, but where repeated heating and cooling are encountered, causing severe internal stresses and consequent cracking, we recommend the use of Maxhete Nos. 2 or 4. Its resistance to scaling at temperatures up to 1150° C. is excellent. Can be supplied as bars, forgings, sheets or castings.

Maxhete No. 4.

(Austenitic high nickel-chromium steel).

This material has the highest strength values at elevated temperatures of any of the Maxhete steels, coupled with excellent scale-resisting properties. Can be used with safety for fluctuating temperatures up to 1150° C., for furnace parts, e.g., chairs, rails, hearth plates, grids, etc.

It can be supplied in the form of bars, sheets, forgings or castings.

Maxhete No. 5.

(High nickel-chromium alloy 60/20).

Has great resistance to scaling and is not subject to intergranular attack at elevated temperatures. Can be used for parts subject to great fluctuations of temperature up to 1150° C. and even in atmospheres containing sulphur in various forms. It is used largely for carburising boxes, retorts, oil burner parts, and other equipment subject to high heat and fluctuating temperatures.

Can be supplied in the form of bars, forgings or castings.

Maxhete's Coefficient of Expansion per ° C.

Temp.	Maxilvry. A.W.P.	Maxhete.				
		1A.	2	3	4	5
15—200° C.	·0000170	·0000171	·0000155	·0000106	·0000154	·0000124
15—500° C.	·0000178	·0000180	·0000170	·0000115	·0000169	·0000150
15—800° C.	·0000185	·0000185	·0000175	·0000120	·0000176	·0000159

Maxhete's Safe Working Load.

Temp.	Maxilvry. A.W.P.	Lbs. per Sq. Inch. Maxhete.				
		1A.	2	3	4	5
550° C.	9000	11000	9000	8000	12000	8000
600° C.	6500	9000	7500	6000	10000	6000
650° C.	4000	7000	6000	4500	8000	4800
700° C.	3000	5000	4500	3500	6000	3500
750° C.	2000	4000	3500	2500	4500	2500
800° C.	1500	3000	3000	1750	3500	1750
900° C.	—	1000	1000	500	1500	500
1000° C.	—	—	350	100	500	100
1100° C.	—	—	100	—	1500	—
Max. temp.	800° C.	900° C.	1050/1100° C.	1050/1100° C.	1050/1100° C.	1100/1150° C.

Write for Maxhete Folder

EDGAR ALLEN & CO., LIMITED

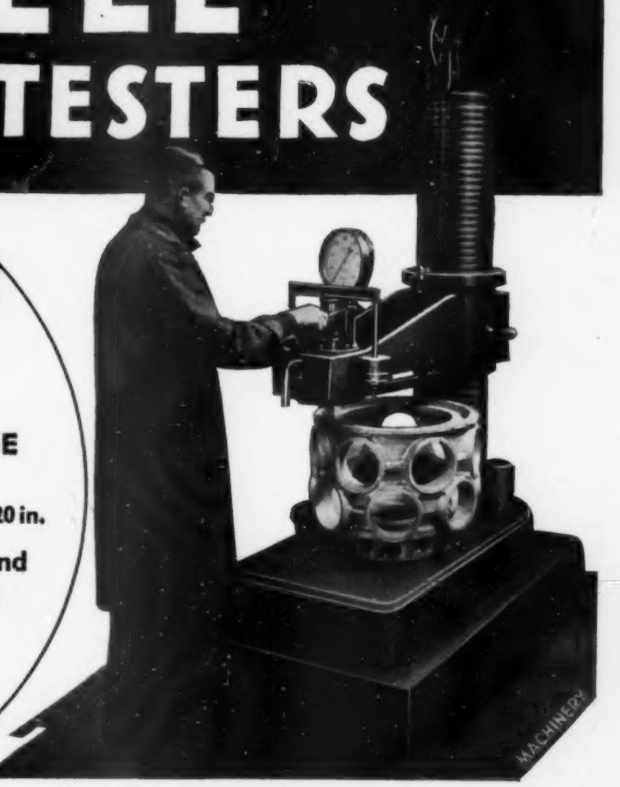
IMPERIAL STEEL WORKS, SHEFFIELD, 9

Telephone: 41054. Telegrams: Allen, Sheffield. London Office: Artillery House, S.W.1

c*

BRINELL
HARDNESS TESTERS

at
Armstrong Siddeley



RADIAL ARM TYPE FOR LARGE WORK

CLEARANCE : VERTICAL 40 in., RADIAL 20 in.

The arm is readily raised and lowered to the position required and the radial movement effected without effort.

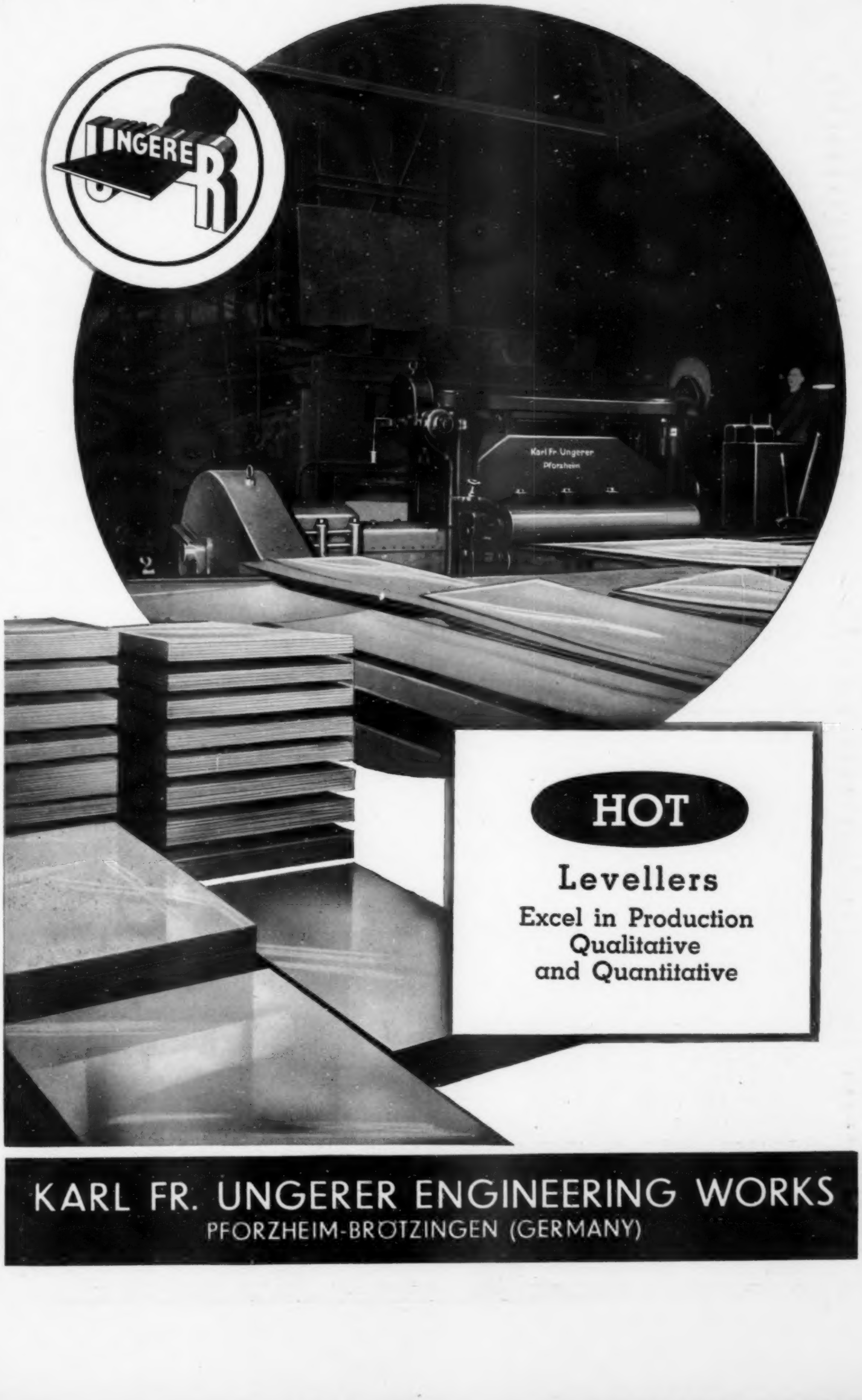
J. W. JACKMAN

AND COMPANY LIMITED,

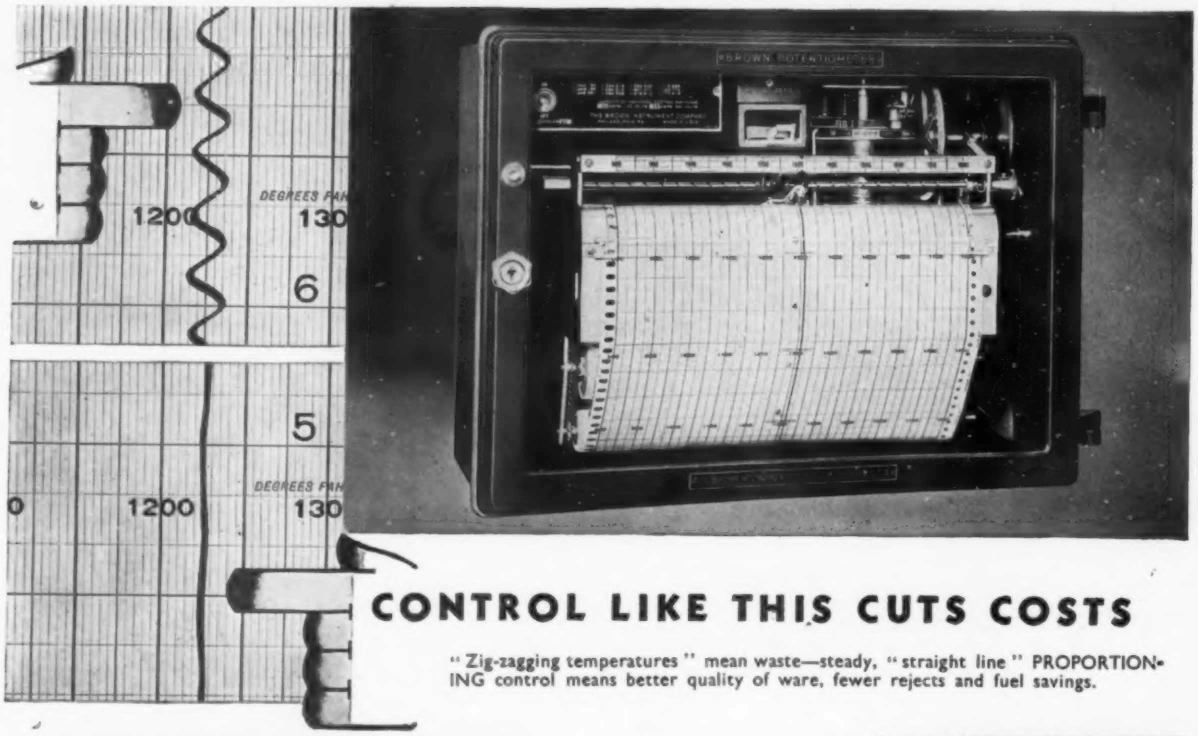
VULCAN WORKS, BLACKFRIARS ROAD,
MANCHESTER.

'Phone : Deansgate 4648/9. *'Grams : Blast, Manchester.*


BARROW STEEL
Open Hearth Acid and Alloy Steels for Forging, Machining and general purposes. Supplied in Blooms, Billets, Slabs, Rounds, Squares, Flats, Hexagons and Special Sections to individual requirements.
All classes of Steel to comply with War Office, Admiralty, Air Ministry and British Standard Specifications; selected Steels to B.S.S. 256 and 351.
BARROW HÆMATITE STEEL CO.
BARROW-IN-FURNESS, ENGLAND


UNGERER
Karl Fr Ungerer
Pforzheim
HOT
Levellers
Excel in Production
Qualitative
and Quantitative
KARL FR. UNGERER ENGINEERING WORKS
PFORZHEIM-BRÖTZINGEN (GERMANY)

Straighten Out These·Costly Temperature Fluctuations



CONTROL LIKE THIS CUTS COSTS

"Zig-zagging temperatures" mean waste—steady, "straight line" PROPORTIONING control means better quality of ware, fewer rejects and fuel savings.

Proportioning Control

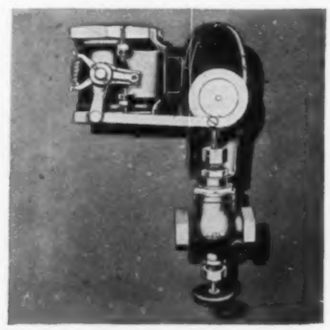
Insures "Straight Line" Results

Efficient and economical operation of kilns, furnaces, lehrs, ovens, etc., *demands* 'straight line' temperature control.

The proportioning control system (combining Honeywell Brown Potentiometer and Proportioning Control Valves) gives you the 'straight line' control that makes for uniformity, reduces wastage and improves quality—factors that mean increased profits.

Proportioning control ensures constant temperature without overshooting or undershooting the required temperature point; in fact it gives the personal touch of a human operator with years of experience plus the reliability of full automatic control. Honeywell-Brown Proportioning Control meets the most exacting demands because it is more adaptable—more flexible . . . it can be applied to your present plant.

Honeywell-Brown Potentiometers are accurate to one-fifth of one per cent. Its broad (12") chart combined with its quite exceptional accuracy enables the slightest deviation to be seen at once. They require standardising only once a month—water renewed every three months.



The "proportioning" valve unit may consist of a globe (fuel) and a butter-fly (air) valve as shown above, or other types in combination or singly powered with the rugged Honeywell-Brown industrial power unit, designed for continuous duty, under the most severe operating conditions.

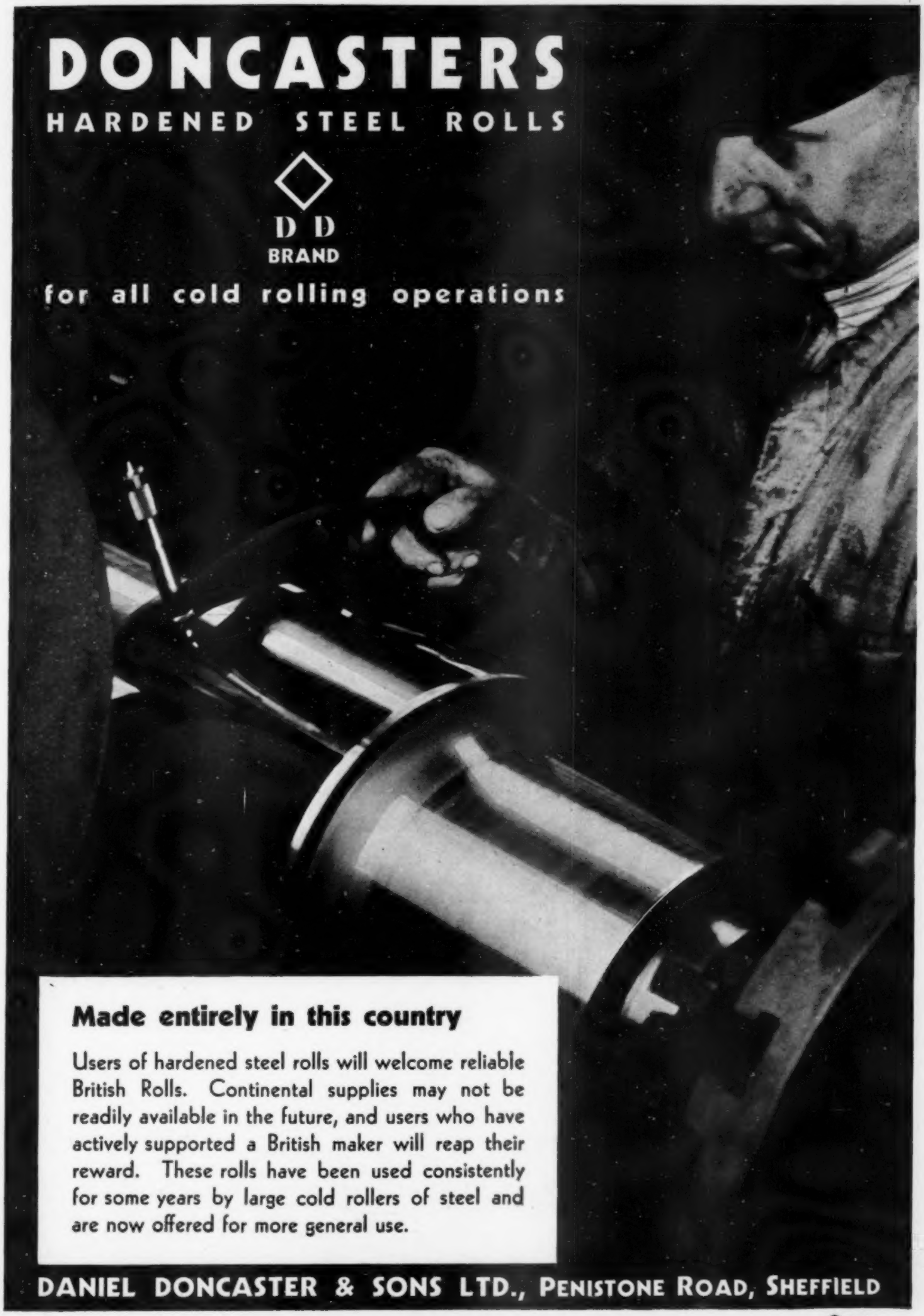
Timing and Voltage

Honeywell-Brown Control valves proportion *exactly* through an infinite number of steps and also maintain a constant pressure.
Power units are supplied for all standard A. C. voltage frequencies: valves to suit and control requirements.

HONEYWELL-BROWN Ltd.

70 St. Thomas' Street, London, S.E.1 'Phone: Hop 0471

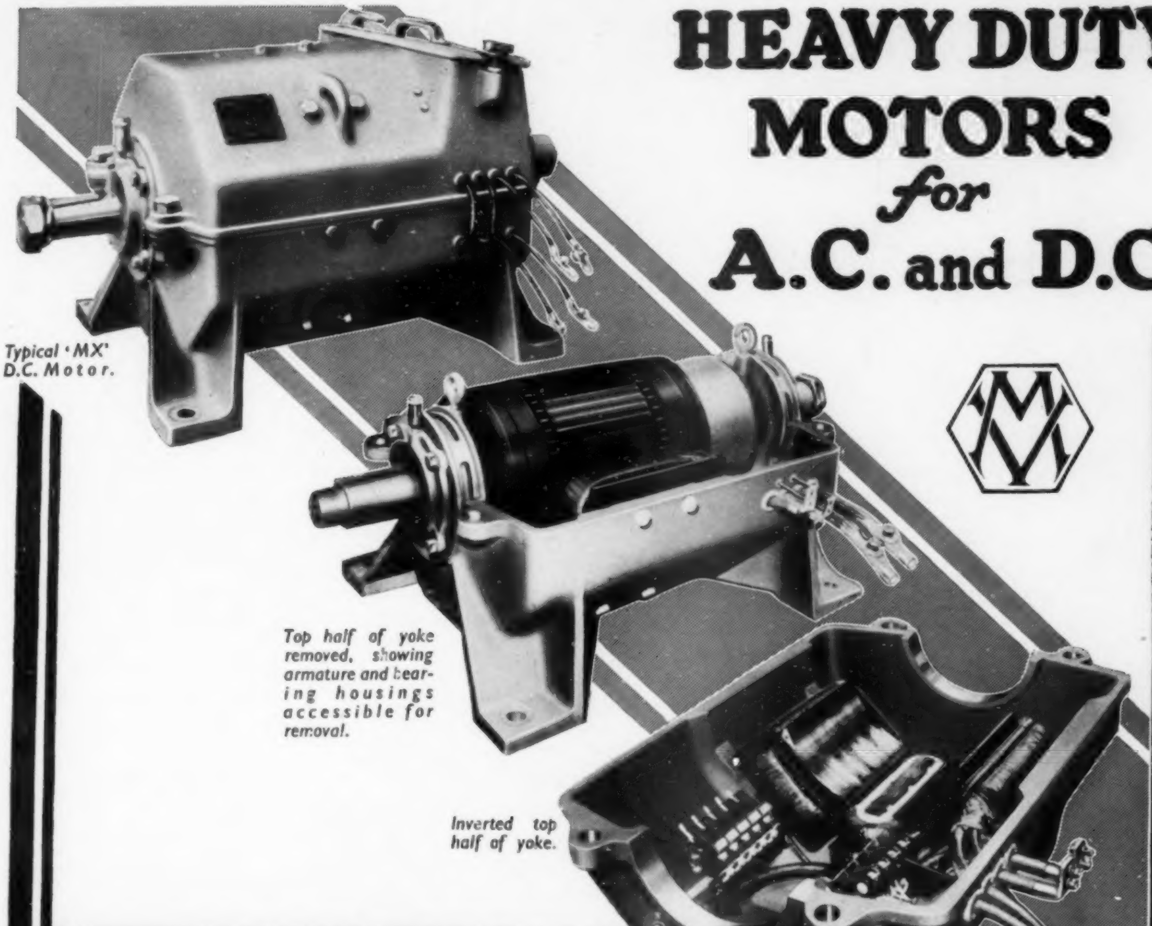
"TO MEASURE AND CONTROL IS TO ECONOMISE"


DONCASTERS
HARDENED STEEL ROLLS
D D
BRAND
for all cold rolling operations
Made entirely in this country
Users of hardened steel rolls will welcome reliable British Rolls. Continental supplies may not be readily available in the future, and users who have actively supported a British maker will reap their reward. These rolls have been used consistently for some years by large cold rollers of steel and are now offered for more general use.
DANIEL DONCASTER & SONS LTD., PENISTONE ROAD, SHEFFIELD

D.D.1.

D*

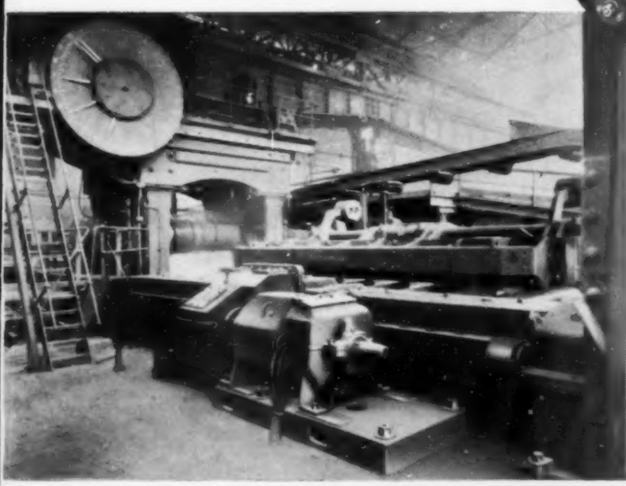
HEAVY DUTY MOTORS *for* A.C. and D.C.



Typical 'MX' D.C. Motor.

Top half of yoke removed, showing armature and bearing housings accessible for removal.

Inverted top half of yoke.

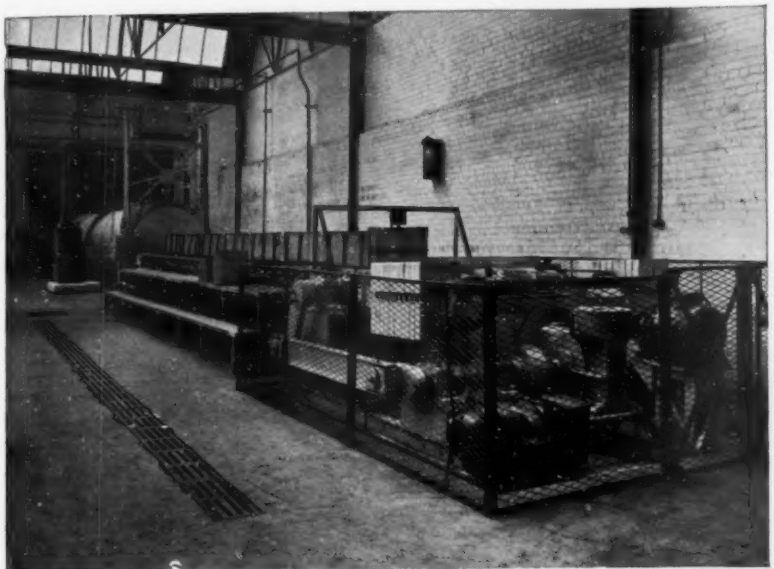


Exceptionally robust in mechanical construction and generously proportioned in electrical design, these "Metrovick" Mill type Motors give reliable service under the most rigorous conditions. The illustrations show the split yoke construction which gives EASY ACCESS and simplified MAINTENANCE.

J/S701

METROPOLITAN Vickers
ELECTRICAL CO., LTD.
TRAFFORD PARK ··· MANCHESTER 17.

See the METROVICK WELDING EXHIBIT Stand 11, Row 'H' at the Engineering & Marine Exhibition, Olympia.
ARC-WELDING EQUIPMENTS ATOMIC HYDROGEN WELDING AUTOMATIC WELDING RESISTANCE WELDING ELECTRODES.



1

2


G.E.C.
ELECTRIC
FURNACES
ON
OFF
HEAT TREATMENT
with simple operation,
precise control, uniformity and economy
BRIGHT ANNEALING
of a standard that enables the product treated
to be delivered literally from furnace to
customer
STEEL MELTING
under ideal metallurgical conditions

METALLURGIA

The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER.)

Contributions suitable for the editorial pages are invited. Photographs and drawings suitable for reproduction are welcome. Contributions are paid for at the usual rates.

PRINCIPAL CONTENTS IN THIS ISSUE:

Subscription Rates throughout the World - - 24/- per annum, Post free.

Published Monthly by the Proprietors, THE KENNEDY PRESS LIMITED, at 21, Albion Street, Gaythorn, Manchester.

Telegrams: "*Kenpred,*" *Manchester.* *Telephone: Central* 0098.

METALLURGIA

THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER".

SEPTEMBER, 1937. VOL. XVI, No. 95.

Metallurgical Developments and Technical Institutes

THE meetings of the Institute of Metals and the Iron and Steel Institute, reviewed in this issue, serve to emphasise the ceaseless efforts to improve the materials of service to the engineer, to develop new materials to meet new conditions, and to assist manufacturing operations. Although nothing of a spectacular character has been presented at these meetings, the investigations discussed indicate steady progress towards a fuller knowledge in many fields of metallurgical activity.

The effect of materials on the performance of the aero engine, referred to by Dr. D. R. Pye in the autumn lecture before the Institute of Metals, is only one of the many fields in which metallurgical developments have played a very important part, and though many problems remain to be solved, the progress made in recent years has contributed, in a large measure, to the success achieved with aircraft. Attention has been directed to the importance of reducing weight, increasing power, and to longer life under service conditions. In addition to special steels which have been developed, the use of aluminium and magnesium alloys has assisted in supplying these requirements. Of outstanding importance is the increasing application of magnesium alloys, both as forgings and castings, in low-stressed parts.

Applications of new alloys or developments of existing alloys generally begin in a very tentative manner, and are invariably preceded by extensive investigations which may, and frequently do, involve years of study before sufficient knowledge of a particular alloy is available to warrant a full-scale test. Even when an alloy is put into service it is the subject of continuous study, with a view to its improvement, particularly in the manufacturing technique employed. Thus, in addition to the progress of scientific discovery in the field of metallurgy, the perfecting of the practice of manufacture, forging, rolling, or casting, expert manipulation with proper equipment, and the development of a full knowledge and ability to carry through suitable heat-treatments, are all essential to the successful development and application of both ferrous and non-ferrous metals and alloys.

Progress in these directions is admirably illustrated in the development and application of corrosion- and heat-resisting metals. The wastage of metals due to corrosion has long been a major engineering problem, yet it is only a little more than twenty years since the resistant qualities of chromium were discovered and the first corrosion resistant chromium steel manufactured. At that time the number of metals available for use in the chemical industry, for instance, was comparatively limited, but new developments in chemical processes created a demand for new metals and alloys suitable for high and low temperatures, and resistant to many types of severe corrosion and scaling. In a relatively short time remarkable progress has been made not only in the development of alloy steels, but also in the development of many non-ferrous metals and alloys for such service, which have been largely responsible for the remarkable progress in certain industries during recent years.

With regard to corrosion, it is very unlikely that any one metal or alloy will be developed to provide the remedy for all kinds of corrosion. Many factors influence the selection of any metal or alloy possessing corrosion-resistant properties, not the least of which is the economic factor. Controlling the ravages of corrosion, so far as iron and steel are concerned, is effected on a large scale by the use of protective coatings. This method is adopted not because modern corrosion-resisting alloys are not effective, but because these alloys are expensive, and can only be used for the construction of the larger engineering structures when price is a minor consideration.

The term "corrosion-resistant" in its application to metals is purely a relative term. Much depends upon what is expected from the material. The services vary so much that reasonable resistance to many forms of corrosion may be provided by low alloy steels, and considerable success has been achieved in the development of several low-cost alloy steels possessing good mechanical properties and corrosion-resistant properties much superior to ordinary carbon steels for structural purposes.

Whatever the service required of any part or complete structure, the problem of the engineer is to select the metal, whether ferrous or non-ferrous, that will best serve its specific purpose at the lowest ultimate cost. This does not mean the lowest first cost, but the lowest cost with regard to the service obtained, and so great has been the advancement of metallurgical science and manufacturing technique that for almost each particular purpose the engineer has a wide choice depending upon whether cost is of greater importance than service.

Despite the advances which have been made over recent years, much remains to be done in determining how various engineering problems and other metallurgical problems can best be solved, either by the materials at present available or by improved types of materials. All the various branches of engineering present the metallurgist with problems. Thus, mining, electrical, textile, chemical, hydraulic, automobile, aero, marine, and railway engineering and shipbuilding, as well as general engineering work, present problems for scientific consideration and ceaseless study is necessary to meet the constant demands for better materials: materials which can be readily forged, welded, or cast, and generally capable of easy manipulation and subsequent machining.

The essential function of metallurgical technical institutes is to afford opportunities for the consideration and discussion of scientific and technical problems arising in the operation and development of the processes and improvement, modification or utilisation of the various metals and alloys developed. The work presented at the recent meetings, reviewed in this issue, it will be noted, is not confined to fundamental scientific research, but also includes investigations that come very close to the immediate industrial needs. In addition, however, they provide opportunities for that intimate contact with manufacturing operations as a result of works visits which are becoming an increasingly important part of these meetings.

Many regular features have been unavoidably omitted from this issue owing to pressure on our editorial space. They will be resumed in the October issue.

THE INSTITUTE OF METALS

Annual Autumn Meeting in Sheffield

This Meeting proved most successful, not only in its contribution to metallurgical progress, but in its promotion of social intercourse amongst members and friends who otherwise would be unlikely to meet. It provided facilities for seeing Sheffield and its environs and to visit some of the pioneer works of the staple industry with which her name is associated throughout the world. In this and following articles is given a brief account of the Meeting, the technical sessions, and the Works visits, with an introduction by the President of the Institute, Mr. W. R. Barclay, O.B.E.

AN interval of some eighteen years has elapsed since the Institute held its last Autumn Meeting in Sheffield, and the opportunity of renewing acquaintance with this famous steel centre has been eagerly welcomed by a number of workers in the non-ferrous industries. A meeting of non-ferrous metallurgists in Sheffield with its great steel and iron works affords a means of interchange of ideas and comparison of methods and technique which cannot but be of advantage to both sections of metallurgy.

The genial President of the Institute.

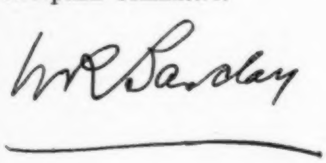
Members of the Institute of Metals find much of real educational value in visits to such works as those on the programme of the Sheffield Meeting of 1937, and the success of this gathering must be estimated not so much by the Papers and Discussions of the Institute at its formal meetings as by the direct and indirect influence of these stimulating contacts.

The technical papers read at the present meeting will possibly be regarded by some of those attending as having a more theoretical than practical bearing. It should, however, always be realised even by those of most severely practical outlook that studies of the fundamental constitution of a particular series of alloys have often great potential value to the industrialist of the future who will be continually seeking new alloys to meet the steadily enlarging demands of the engineer. Even in cases where the alloy system investigated appears to have at the moment little or no industrial value such constitutional studies often bring out certain factors which throw light on baffling phenomena encountered in other and more generally applicable industrial alloy systems.

It should also be noted that one or two at least of the papers of the Sheffield meeting have a definitely practical bearing, notably those on the testing of zinc coatings, and the effects of cold rolling on the structure of certain alloys. The latter Paper, i.e., by Dr. H. A. Unckel, is of particular interest as being contributed by a works engineer of high standing in Sweden, whose outlook is necessarily that of a responsible industrialist.

The determinations of mechanical properties and precision extensometer measurements are also subjects of vital interest to both academic and industrial metallurgists, for in these days of more and more exacting requirements of the engineering and allied industries precise knowledge of the properties of materials is of the highest importance.

I hope I may be allowed in a concluding sentence to express the appreciation and gratitude of the Council and Members of the Institute to our Sheffield hosts for the most admirable arrangements and hospitalities of this meeting. Particular mention must be made of the work and enthusiasm of Professor Andrew and his secretary, and the members of the Reception Committee.



Civic Welcome

This Meeting, held in Sheffield by invitation of the local section, and with the co-operation of the industrialists of Sheffield and of the University of Sheffield, was the twenty-ninth annual autumn meeting of the Institute of Metals. It was preceded by a reception, held at the Department of Applied Science, St. George's Square, where members and their wives and friends were received by the Lord Mayor and Lady Mayoress, Councillor Mrs. A. E. Longden and Miss Mary Longden, the Senior Chancellor, Lieut.-Col. Sir Henry Stephenson, Bt., and Lady Stephenson and the President of the Institute.

In welcoming members and their friends to the City of Sheffield, the Lord Mayor said that the choice of the City for such a conference proved that it had its particular attraction. Metals were the main source of its prosperity and a subject about which many Sheffield men knew a good deal. She thought that the City was in a very enviable position in being conveniently located with regard to minerals and in having a good water supply. Since 1929, the City has experienced some lean times, but to-day trade is wonderfully improved, a fact which is reflected in the happiness and contentment of its people. On behalf of the City of Sheffield, she accorded members a most hearty welcome and trusted their deliberations would be successful and that the social arrangements would be such as would provide happy memories of the Sheffield Meeting. The short address of welcome was supported by Sir Henry Stephenson and Mr. Barclay responded in a few well chosen words.

Autumn Lecture

A very brief business meeting followed at which were announced names of officers nominated for the year

1938-39: President, Dr. C. H. Desch; Vice-President, Professor J. H. Andrew; Member of Council, Dr. J. W. Donaldson, Eng. Vice-Admiral G. Preece, and Mr. H. S. Tasker. Immediately afterwards the Sixteenth Autumn Lecture was delivered by Dr. D. R. Pye (Director of Scientific Research, Air Ministry) on "Metallurgy and the Aero Engine," Dr. Pye emphasised the recent increase in the power output from aero engines achieved by improvements in the quality of fuel, but stated that this increase of power could not have been achieved without parallel improvements in the materials of construction to meet the severe conditions of heat flow and mechanical loading. He discussed many aspects of this subject to which reference is made elsewhere in this issue.

Sessions and Visits

The meeting was continued the following day when several papers were presented for discussion at a technical sesssion. Mr. W. O. Alexander and Dr. D. Hanson dealing with the effect of heat-treatment on the hardness and electrical resistivity of copper-rich nickel-aluminium-copper alloys; Mr. W. O. Alexander and Mr. N. B. Vaughan presenting work on the constitution of the nickel-aluminium system; Mr. L. Kenworthy dealt with methods for testing zinc coatings; Mr. D. W. Ginns presented the results of some investigations on the mechanical properties of carbon steels, copper, brasses and aluminium alloys when broken in tension at very high speeds; while a method of using a precision extensometer for creep experiments on tin was explained by Mr. B. Chambers. Meanwhile the ladies visited the Dukeries and Firbeck Hall Club.

Several works were visited during the afternoon, including the Templeborough Works of United Steel Companies Ltd., the English Steel Corporation Ltd., Brown Bayley's Steel Works Ltd., and Messrs. Mellowes and Co. Ltd, and members and their ladies attended a reception kindly given by the Lord Mayor of Sheffield in the evening at the Town Hall. An excellent programme of music was provided and dancing proceeded until midnight.

A further technical session, held the following morning, dealt with a number of interesting subjects including a study of the deformation of the macrostructure of two-phase alloys by cold rolling. Although the author Dr. H. A. Unckel, was unable to be present, considerable discussion took place in which Professor F. C. Thompson, Dr. C. H. Desch, Dr. R. Genders, and Dr.-Ing. W. J. P. Rohn participated. Dr. C. Sykes and Mr. H. Wilkinson described their work on the transformation in β brasses; a study of the mechanical properties of tin-rich antimony-cadmium-tin alloys was introduced by Mr. W. T. Pell-Walpole; the determination of aluminium in the presence of metallic aluminium by Messrs. G. B. Brook and A. G. Waddington; and a further paper by Dr. D. Hanson and Mr. Pell-Walpole on the constitution of tin-rich antimony-cadmium-tin alloys.

The works visited after lunch included Messrs. Thos. Firth and John Brown Ltd., Messrs. Edgar Allen and Co. Ltd., Messrs. Hadfields Ltd., and Messrs. Walker and Hall Ltd. In the evening a banquet and dance was held at the Royal Victoria Station Hotel which will long be remembered by those who participated. The concluding day of the meeting was devoted to a sightseeing expedition through some of the beauty spots of Derbyshire.

Technical Sessions

It is not possible to reproduce here the papers presented at this meeting, but readers will probably find the following brief summaries of considerable value.

COPPER-RICH NICKEL-ALUMINIUM-COPPER ALLOYS

PART I.—THE EFFECT OF HEAT-TREATMENT ON HARDNESS AND ELECTRICAL RESISTIVITY.

The primary object of the investigation described in this paper by Dr. W. O. Alexander and Professor D. Hanson, was to study the factors governing the hardening in copper-rich alloys containing up to 8·5% aluminium and 10% of nickel. A secondary object was to examine the scope of electrical resistivity measurements for the accurate determination of solid phase limits in a ternary system. Some 56 alloys were cast and extruded, and the effect of heat-treatment on the hardness and electrical resistivity was examined.

The results indicate that above 800° C. all the alloys consist of uniform α solid solution. When heated at temperatures below 800° C. some of the alloys harden, and their electrical resistivity decreases. The results reveal the approximate limits of the α solid solution, while the manner of the changes in properties at lower temperatures implies precipitation of new phases, the origin of one lying in the direction of the nickel-aluminium binary system.

The greatest decrease in α solid solubility occurs over the temperature range 750° to 550° C. The limit of α solid solution at 400° C. and below is of the order of 1·5% nickel and 0·2% aluminium. The disposition of the alloys showing maximum hardening capacity, together with minimum electrical resistivity, agrees with the optimum ratio 4 : 1 nickel to aluminium. The changes of electrical resistivity and hardness on annealing at lower temperatures of alloys quenched from 900° C. are similar to those occurring in other age-hardening systems.

THE CONSTITUTION OF THE NICKEL-ALUMINIUM SYSTEM

Micrographic evidence obtained in the course of the investigation of the constitution of the nickel copper-rich aluminium-nickel-copper alloys, pointed to the existence of a phase which could not be identified by reference to the only published diagram for nickel-aluminium alloys, due to Gwyer. This paper, by Dr. W. O. Alexander and Mr. N. B. Vaughan, describes a re-examination of these alloys.

The system has been studied by thermal and micrographic methods and a new diagram has been produced which remains substantially as determined by Gwyer, except that the compound described by Gwyer as $NiAl_2$ is shown to be Ni_2Al_3. Examination of the microstructures of slowly cooled and heat-treated specimens lead to the tentative modification of Gwyer's diagram by the introduction of an additional phase, which has been termed θ. The range of this phase field appeared to be from 85·5 to 88% nickel, for alloys with compositions between these limits underwent no change in structure on cooling from 1,400° C. An X-ray spectrogram showed that the θ phase has a face-centred cubic lattice with superlattice, and probably corresponds with the intermetallic compound Ni_3Al. This phase is formed as the result of a peritectic reaction which occurs at 1,395° C. between NiAl solid solution and liquid, and it yields a eutectic with α solid solution at 1,385° C.

The nickel-rich alloys in general possess marked heat-resistance, and maintain their hardness at elevated temperatures. The hardness property is capable of modification by heat-treatment.

THE METHODS OF TESTING ZINC COATINGS

A common method of protecting iron and steel against corrosion is the application of some form of zinc coating. These coatings vary in quality and composition, and the necessity arises for some test or tests which can be applied to the coating to indicate its protective value under the conditions to which it will be subjected in service. A method which is sometimes employed for this purpose is an accelerated laboratory corrosion test. Although certain tests of this type have been shown to be of value, the results obtained are apt to be misleading, and in general their interpretation is to be approached with some caution, unless the method employed has previously been subjected to very careful correlation with actual service life.

A more satisfactory type of measurement is the determination of what are believed to be the most important

properties of the coating from a corrosion-resistance point of view—namely, weight thickness, uniformity, structure, composition, and porosity, and this paper by Mr. L. Kenworthy is concerned with a description and review of the various methods which have been proposed for this purpose. Even this type of measurement, however, suffers from the disadvantage that the relative importance of the properties mentioned depends on the condition of the exposure. For atmospheric conditions, for example, it has been established that, compared with thickness, the composition is relatively unimportant, but for other types of exposure the most desirable qualities of the coating are still incapable of clear definition, and until such knowledge is forthcoming, indirect tests, while of considerable value, do not provide an entirely satisfactory means of assessing the protective value of a zinc coating.

To test for thickness and composition, the electrolytic method, employing potential measurements, is recommended where possible. In other cases, average weight determinations by chemical stripping is advised, supplemented by micro-examination and/or chemical analysis of iron in the stripping solutions. Discontinuities and general distribution of the coating may be conveniently investigated by means of the Preece test. In routine testing, Mr. Kentworthy is aware that the claims made for the Preece test regarding simplicity and rapidity are undeniable, but states that in view of the serious shortcomings of the test it should be subjected to a correction factor for the type of coating being tested, and, in addition, checked periodically by some method of actual weight determination. In this capacity the electrolytic test is already being used in this country.

THE MECHANICAL PROPERTIES OF SOME METALS AND ALLOYS BROKEN AT ULTRA HIGH SPEEDS

It has been observed that stresses greatly exceeding the normally accepted values of ultimate strength can be applied to iron and copper wires for very short intervals of time without the occurrence of rupture. This fact is now generally accepted for all the more common engineering materials. Apparently there is no available data of the behaviour and mechanical properties of these more common materials during high-speed stressing, and the investigation described in this paper by Mr. D. W. Ginns was undertaken to meet this need.

The mechanical properties of carbon steels, copper, brasses, and aluminium alloys were investigated when broken in tension at very high speeds. The average time taken to reach the yield-point is 0·001 second, and to fracture 0·005 second. For work at very high speeds, the use of the mechanical recording apparatus was out of the question, on account of inertia effects. Electrical methods, using the cathode ray oscillograph, were therefore developed. The tests were carried out on a new type of impact machine (British Patent No. 448,130), the salient feature of which is the method of applying the load. A pressure resistance method was used for measuring the stress, and a photo-cell method for strain, the two being combined to give a direct diagram on the cathode ray oscillograph.

It is shown that, compared with the ordinary commercial tensile test values, the yield-point is increased very considerably, over 100% increase being recorded for some materials; the maximum stress is increased by a much smaller amount; the percentage elongation and the percentage reduction of area show comparatively small changes; and the types of fracture are almost identical with those obtained in the slow test.

PRECISION EXTENSOMETER MEASUREMENTS ON TIN

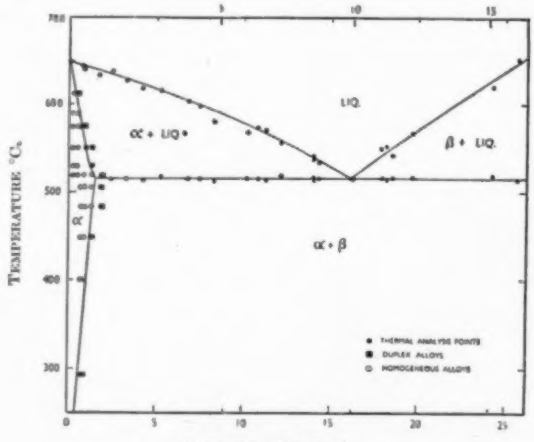
Mechanical tests on a metal may be designed for either of two objects: to test the suitability of the metal for a given purpose, or to investigate its fundamental physical properties. The same tests are rarely suitable for both purposes, because the engineer's type of test usually deals collectively with a number of simple properties, while the fundamental test must deal with one property only. This paper by Dr. Bruce Chalmers deals with a fundamental investigation of the mechanical properties of tin. It deals with the determination of the creep limit and its variation with the size and arrangement of the crystals. It also describes an investigation of the effect of stresses close to the creep limit—i.e., the border line between elastic and plastic phenomena.

For this investigation a precision extensometer, reading by means of optical interference fringes to strains of 10^{-7} cm./cm., is used for creep experiments on tin. The results are given under three headings: (*a*) single crystals; (*b*) specimens consisting of a few crystals with longitudinal crystal boundaries; and (*c*) specimens consisting of small crystals. The results show that the change of orientation across a crystal boundary affects the mechanical properties of the boundary, and the relation between recovery and creep, and the forms of the creep curves are discussed.

ALLOYS OF MAGNESIUM

PART VI.—THE CONSTITUTION OF THE MAGNESIUM-RICH ALLOYS OF MAGNESIUM AND CALCIUM.

It has been shown that additions of small amounts of calcium cause an improvement in the mechanical properties of some magnesium alloys at high temperatures; they also reduce the tendency of magnesium and its alloys to burn, and appreciably reduce the amount of scale formed during annealing. The work described in this paper by Dr. J. L. Haughton is part of the investigation of the alloys of magnesium being conducted at the National Physical Laboratory, under the direction of Dr. C. H. Desch, F.R.S., for the Metallurgy Research Board. It has been carried out to check the existing equilibrium diagram, and has been extended to alloys containing up to 26% calcium in order to determine accurately the composition of the eutectic.



Equilibrium diagram of the magnesium-calcium alloys containing up to 20% calcium.

The complete system was investigated in 1911 by N. Baar, who published a diagram of the magnesium-calcium alloys containing up to 26% calcium. As a result of the present investigation, the equilibrium diagram, which is reproduced here, differs somewhat from that determined by Baar. The author discusses the new determination of the constitution under (*a*) the liquidus; (*b*) the eutectic; and (*c*) solubility limits.

(*a*) Except for alterations introduced by the change in composition of the eutectic, the liquidus found differs little from that given by Baar.

(*b*) The eutectic temperature (517° ± 1° C.) is in very good agreement with that found by Baar, who gave it as 514° C. The eutectic composition found in the two

investigations is, however, very different: Baar gave it as 19% calcium, while the present investigation shows it to be 16·2%. The determination of the composition was rendered difficult by the fact that errors in the thermal and chemical analyses introduced a certain amount of uncertainty into the location of the position of the liquidus. The error in composition of the eutectic as determined from the intersection of the liquidus curves is unlikely to be greater than ± 0·5%; the probability of its being so great as this is reduced by the fact that micrographic examination of a chill-cast 16·27% alloy suggested that it was pure, or very nearly pure, eutectic.

(*c*) The solubility limits were determined by the microscopic examination of annealed and quenched specimens. Magnesium dissolves about 1·8% of calcium at the eutectic temperature; at 250° C. the solubility has decreased to about 0·5%.

DEFORMATION OF THE MACROSTRUCTURE OF SOME TWO-PHASE ALLOYS BY COLD-ROLLING

The deformation phenomena occurring during the rolling process have been investigated by many workers. In these investigations the material was assumed to be homogeneous. The rolling process, however, is widely employed for alloy systems which are not homogeneous, but which consist of particles possessing different hardness, and the deformation of such materials present problems which have a distinct practical importance. In the cold-rolling of an alloy with phases of different hardness, deformation will not take place in the same way as a homogeneous metal. The subject opens a new and wide field for investigation, but this paper by Dr.-Ing. Hermann Unckel deals only with some of the many aspects of the problem. In addition to certain general considerations, some experiments with a few two-phase alloys are reported as examples, and some of the results are treated mathematically in further consideration of the problem.

The materials were chosen to represent certain characteristic cases, and not with regard to their technical application. The compositions included a leaded brass, 63% copper, 27% zinc, 10% lead; an α-β brass, 63% copper, 37% zinc; a complex brass (Ellis type), 55% copper, 3% aluminium, 1·5% iron, 4% manganese, 36·5% zinc; a copper-iron alloy, 94% copper, 6% iron; a tin-bronze, 90% copper, 10% tin; a high-silicon aluminium alloy, 88% aluminium, 12% silicon; and an aluminium-copper alloy, 92% aluminium, 8% copper.

As a result of the investigation, it is shown that harder particles embedded in a softer matrix deform less, and softer particles somewhat more, than the matrix. Through the different relative flow of inclusion and matrix, additional plastic flow must take place in the vicinity of inclusions or second phase particles. Thus, extra stresses are set up in the material leading to an increase in brittleness, as, for example, with aluminium, silicon, and brass containing lead. The deformation of the different phase particles can be followed by microscopically measuring the mean compression of a very great number of grains by statistical methods.

In alloys consisting of a ground mass with inclusions of a harder phase, the deformation of the embedded particles is less than that of the test-piece as a whole or of the matrix, and becomes nil if the stress necessary for deformation of the inclusion exceeds a certain value. In alloys consisting of a matrix, with inclusions of a softer phase, the deformation of the latter is somewhat greater than that of the matrix. In all cases the deformation within the material is governed by the principle of minimum work of deformation. The gain in work by a greater compression of a softer particle or less compression of a harder particle being at a certain stage of equilibrium counterbalanced by more additional flow in the matrix.

If the fundamental relationship between the relative deformations of inclusion and matrix and the relative deformation stresses were known exactly by experiment, the work of deformation and the prevailing mean stress could be calculated and the flow round the inclusion found by graphical methods.

TRANSFORMATION IN THE β BRASSES

This transformation, discussed by Dr. C. Sykes and Mr. H. Wilkinson, has been investigated theoretically on on the basis of two different assumptions. Bragg and Williams[1 2] assume that the energy of a given structure is determined by the average degree of order throughout the whole structure—i.e., by the long-distance or superlattice order. The whole of the change in energy and eutropy is to be found, therefore, below the critical temperature, since superlattice order disappears at this point on heating. Bethe,[3] on the other hand, assumed that interaction occurred only between nearest neighbours, and showed that whilst superlattice order disappears at the critical temperature, a certain amount of local order exists above this temperature, since a tendency for unlike atoms to be neighbours still persists. Local order only disappears completely at very high temperatures; consequently an abnormally high specific heat should exist above the critical temperature. As both theories deal quantitatively with certain features of the transformation which have been investigated experimentally, the authors make a comparison.

The results of this investigation show that an excess specific heat exists above the critical temperature. The Bethe theory gives the better agreement as regards total energy and eutropy change. Consequently, the assumption that interaction occurs only to nearest neighbours must be considered more probable than the more general assumption of Bragg and Williams. In both cases the energy predicted by Bethe's theory is about 10% higher than the value found experimentally, and is not sufficiently compressed into the temperature interval within 200° C. of the critical temperature.

In particular, the theoretical S T curves are a very poor approximation to the actual curves. Their shape is fixed by the assumptions made as to the precise nature of the ordering force, and, as Williams has pointed out, slight modifications are likely to make large changes in the S T curve at the critical temperature. It is not surprising, therefore, that this feature of the transformation is the least satisfactory, since it is unlikely that the form of the ordering force is as simple as Bethe assumes. Further theoretical improvements must be chiefly concerned in the evaluation of the correct S T curve.

CuZn and Cu_3Au are probably amongst the simplest examples of order-disorder transformations which exist, and are the only cases which have been examined experimentally in order to determine whether they obey the various theoretical predictions. It is highly probable that the majority of such transformations will be more complicated (e.g., MgCd, CuAu, etc.) so that any detailed generalisation is best avoided until a large number of different transformations have been studied.

MECHANICAL PROPERTIES OF TIN-RICH ANTIMONY-CADMIUM-TIN ALLOYS

Antimony-tin alloys form the basis of most commercial tin-base alloys and the beneficial effect of antimony on the mechanical properties of tin is well known. In this paper by Professor D. Hanson and Mr. W. T. Pell-Walpole, it is shown that the tin-rich cadmium-tin alloys can be permanently improved by heat-treatment. Investigations have shown that the addition of 1% of cadmium to tin-base bearing metals greatly improves their fatigue strength, indentation hardness, tensile strength, and resistance to pounding.

1 W. L. Bragg and E. J. Williams, *Proc. Roy. Soc.*, 1934 [A], 145, 699.
2 W. L. Bragg and E. J. Williams, *Proc. Roy. Soc.*, 1935 [A], 151, 540.
3 H. A. Bethe, *Proc. Roy. Soc.*, 1935, [A], 148, 422.

The strengthening effect of cadmium in solid solution in tin is much greater than that of antimony. The presence of the δ-phase (principally SbSn) as primary cuboids has no adverse effect on strength or hardness, but the presence of primary ε(CdSb) destroys the useful mechanical properties of the alloys. The maximum combination of hardness, strength and ductility was obtained in those alloys which had finely dispersed precipitates of the δ and ε phases in a α matrix, or finely dispersed ε in a matrix consisting of α (tin-rich solid solution) with a eutectoid of α plus γ (cadmium-rich solid solution).

Tensile and Brinell hardness tests were carried out on 112 alloys containing up to 43% cadmium and 14% antimony. The maximum stable values obtained were of the order of 7 tons/in.^{2}, with 15% elongation on 2 in. and a Brinell hardness of 35, in alloys containing 7 to 9% of antimony with 5 to 7% of cadmium.

Results of a large number of tests showed that there is a definite relationship between tensile strength and Brinell hardness for these alloys. For all the heat-treated specimens a linear relation was obtained: tensile strength in tons/in.^{2}=0·2 × Brinell number. The results for alloys in the rolled and self-annealed condition did not lie in the same straight line as the former, but gave a second relation: tensile strength in tons/in.^{2}=0·23 × Brinell number.

THE DETERMINATION OF ALUMINA IN THE PRESENCE OF METALLIC ALUMINIUM

Determining alumina in the presence of metallic aluminium has always proved a matter of considerable difficulty to the analyst. Many attempts have been made to produce a reliable method, but no really successful process has yet been described. The materials to be examined may vary considerably in alumina content—from aluminium dross containing about 50%, aluminium skimmings with 5 to 15%, to granulated aluminium containing often less than 1% alumina.

Numerous methods of solving this problem have been published, and after a careful review of these methods Messrs. G. B. Brook and A. G. Waddington, the authors of a paper on this subject, came to the conclusion that the process as described and worked by Jander and Baur[1] seemed the soundest from all points of view. Although these workers employed the process for the determination of alumina in aluminium and the separation of constituents of alloys of aluminium, the process also promised considerable advantages in its application to the separation of alumina from aluminium dross, skimmings, and granulated aluminium. A very commendable feature of the process lies in the fact that the alumina is retained in its original form, and the metal content can also be determined from the condensate of the volatilised aluminium chloride.

The authors have investigated this volatilisation process for the determination of alumina in the presence of metallic aluminium, using hydrogen chloride, and describe a modified process, together with the required apparatus, which is claimed to be the most superior of any yet proposed. The complete separation of the metal as chloride, and subsequent conversion to oxide, allows the metallic content of the skimmings and dross to be accurately determined. The determination of inclusions, such as cryolite and flux in metal, is not possible, owing to the breakdown of the fluorides. The authors show that the previously used "total oxidation" method gives high results, owing to the alumina being invariably present in the sample in a hydrated form. It is noteworthy that this volatilisation process has proved equally satisfactory for materials having an alumina content ranging from less than 1·0 to 65%.

THE CONSTITUTION OF TIN-RICH ANTIMONY CADMIUM-TIN ALLOYS

There are a number of ternary systems of which no systematic investigation has previously been made. The antimony-cadmium-tin system was a case in point, and in this Paper Professor D. Hanson and Mr. W. T. Pell-Walpole present their research as an extension of that carried out on the cadmium-tin alloys.

The constitution of antimony-cadmium-tin alloys containing up to 43% of cadmium and 14% of antimony has been established by thermal and microscopical analyses, the results being presented as isothermal diagrams of the various surfaces, and as vertical and horizontal sections through the constitutional model. There are three ternary peritectic reactions at 227°, 209°, and 180° C., respectively. Metastable conditions occur during cooling in parts of the system, but these were related to the stable state which is obtained by prolonged annealing of specimens.

The five phases which occur in the ternary alloys examined are: (1) the ternary tin-rich solutions; (2) the β phase of the cadmium-tin system, with antimony in solution; (3) a cadmium-rich solid solution γ; (4) a hard, white phase very similar to the SbSn of binary antimony-tin alloys: this is termed δ and not SbSn, since it dissolves a considerable amount of tin and cadmium; and (5) a brittle pale bluish-grey phase, similar to that found in the binary cadmium-antimony alloy, containing 50% antimony. In the group of alloys first examined (containing up to 9% antimony and 8% cadmium) this phase occurred only as a fine separation, and in an etched specimen this was so much like the white δ precipitate that it was not recognised as a separate phase until it was observed as a primary constituent in alloys with higher cadmium content, but was unmistakable in the latter state.

CONSTITUTION OF THE COPPER-GALLIUM ALLOYS IN THE REGION 18 TO 32 ATOMIC PER CENT OF GALLIUM

This paper by Dr. W. Hume-Rothery and Mr. G. V. Raynor describes the copper-gallium equilibrium diagram above 420° C. in the region 18–32 atomic per cent. gallium. The results of the investigation show that in this range three distinct modifications of the β phase are formed, and there is evidence that a fourth modification of the β phase exists at low temperatures, but the whole system is so complicated that the authors thought it advisable to publish the results which definitely establish the high-temperature portion of the diagram.

The results show that the β phase, stable at high temperatures, has a considerable range of composition which diminishes rapidly with decreasing temperature until a eutectoid point is reached at 618° C. The phase boundaries for this modification of the β phase agree well with the diagram of Weibke, but, in contrast to the results of this investigator, the eutectoid transformation is not a reaction of the type $\beta \rightleftharpoons \alpha + \gamma$, but $\beta \rightleftharpoons \beta' + \gamma$, where the β′ phase exists over a narrow range of composition in the region 22·3 atomic per cent. gallium. The β′ phase is stable above 475° C., at which temperature another transformation takes place with the formation of the β″ phase existing over a narrow range of composition in the region 21·5 atomic per cent. gallium.

Invitation To Hold Next Autumn Meetings In America

The American Institute of Mining and Metallurgical Engineers and the American Iron and Steel Institute have extended a cordial invitation to the Institute of Metals and the Iron and Steel Institute to hold their respective 1938 autumn meetings in America. The invitation has been accepted, and arrangements are in process of being made. Obviously, the preparation of suitable programmes will involve considerable work, and in order to facilitate arrangements, the co-operation of members is desired without delay. The secretaries of the respective Institutes desire to be notified if a member is likely to attend. There will be no obligation, but it is necessary to have a rough idea of the number likely to participate in these meetings.

[1] G. Jander and F. Baur. *Z. angew. Chem.* 1927, 40, 488.

Some Notable Sheffield Works

Many of the foremost manufacturers of Sheffield's staple products opened their works to members of the Institute of Metals on the occasion of the recent Annual Meeting, and, as it was impossible to visit all these works, a brief description of the various visits, together with a short account of the firms, given in this article, will be of interest.

GENERALLY, it can be stated that, in regard to metallurgical development, scientific progress does not reach its highest phase until the proper technique is developed for its application to normal practice; for this reason it is important to associate works visits with the study of scientific problems. In addition to this aspect, however, works visits of this character provide facilities for seeing the results of progress of scientific discovery in the field of metallurgy, opportunities for discussing production problems and for seeing the expert manipulation of tools and materials to meet growing demands. Actual personal contact with works is, of course, of greater value, but, as several visits were arranged at similar times only one of which could be taken advantage of, a brief description of the various works visited will be useful.

Steel, Peech and Tozer Ltd.

THIS is the parent company of the United Steel Companies Ltd., and it can be stated that the origin of this group of companies is due to the late Mr. Henry Steel. He conceived the idea of reducing waste in materials, time and transport by eliminating overlapping and duplicating of processes, and so brought together a number of prominent companies, each with well established reputation and of such varying activities as would make them, as a combination, self-supporting and able to supply all the raw and semi-finished materials needed.

There is much of historical interest at the Templeborough Works, especially in regard to metal working by the Romans, as was revealed by excavations in 1919 for the site of the present steel plant.

The annual productive capacity of the United Steel Companies is approximately 800,000 tons of pig iron, 1,700,000 tons of steel and 3,000,000 tons of coal, and, of course, the many by-products.

The Templeborough Steel Works and Mills and the United Strip and Bar Mills are twin enterprises, producing a range of strip from 0·030 in. to slabs up to 10 in. thick. The furnaces and mills of the Templeborough Works, adjoining the older Ickle Works, extend for nearly two miles along the banks of the Don and are equally convenient in location for handling raw materials and distributing the output.

The large cogging mill at Templeborough Works.

Disc mill in operation at Steel, Peech and Tozer's Works.

The various shops were visited in logical sequence, starting with the Templeborough melting shop (Steel, Peech and Tozer), with 14 eighty-ton open-hearth furnaces in its quarter-mile length. The furnaces are in continuous operation, only being suspended for routine attention such as relining.

Car casting is used and the ingot moulds are placed on bogies after casting, they are then run under the ingot stripper where the moulds are lifted off the ingots and the ingots conveyed in an upright position to the soaking pits. At the time of the visit, the melting shop was producing more than 11,000 tons of ingots each week.

The soaking pits consist of 3 holes of 24-ingot capacity each, and 14 holes of 10 ingot capacity each, forming the two sides of the 365 × 86 ft. building. The pits are gas fired from a battery of three gas producers. A uniform temperature of between 1,140 and 1,200° C. is maintained.

From the soaking pits the ingots pass to the cogging mill, this being one of the largest in existence. It is of the two-high reversing type, has 40-in. rollers and a 15,000 h.p. drive. It rolls the 5-ton ingots into 6-in. square blooms at a normal speed of 48 r.p.m., although it can be regulated up to 100 r.p.m. The mill motor is controlled on the Ward Leonard principle, by which the inertia of the flywheels is used to provide a great proportion of the energy required for reversal of the main motor without producing any serious reaction in the supply line. Reversal from 48 r.p.m. forward to the same speed in reverse is 2·5 seconds, or from 100 r.p.m. forward to 100 r.p.m. reverse 4·5 seconds. The mill is capable of rolling 18,000–20,000 tons of ingots, and has accomplished an output of 17,500 tons in a week.

The billet mill was next inspected, where the cogged blooms are delivered in a straight line to the shears capable of dealing with 10 in. × 10 in. hot blooms. The bloom is

Bar Mill and Finishing End at Templeborough Works.

then delivered by live rollers to a 21-in. continuous billet mill with four stands of rolls for reducing a 6·25-in. bloom to four inches square. For any further reduction the blooms are delivered by live rollers to an 18-in. continuous mill with six stands of rolls capable of reducing the bloom to 1·75 or 1·5 in. square. The billets are then cut to 30 ft., of other length, by steam-driven flying shears. Blooms for rolling into slabs or rounds, etc. are skidded across to a parallel line to the slab shears capable of shearing up to 18 × 6 in. From the flying shears, the billets pass by live rollers to the hot bank.

At the Ickle works (Steel, Peech and Tozer) the tyre and disc mill was seen. This is one of the largest railway tyre plants in the world, producing flangeless and double flanged tyres from 15 in. to 10 ft. internal diameter. The works include a roughing mill, reheating furnaces, 2,300 ton centre punching press, parting lathes and band saw shop for sawing ingots into cheeses of the required size. Solid disc centres are made in an adjacent shop, the cheeses being roughly pressed, centre punched, then rolled to size and dished under a 2,300 ton press.

The forge and axle shops commanded a great deal of interest, the range of productions varying from 2 in. to 50 in. diameter, equipment being from a 30-cwt. hammer to a 2,200 ton press, the latter being capable of handling ingots up to 60 tons each and used largely for hollow forgings, big die blocks, turbine rotors, locomotive crank axles, etc. The works undertake a very wide range of forgings, and the equipment also includes 30- and 50-cwt. and 4- and 5-ton hammers, much of the work from which is for locomotive application. Heat-treatment and testing facilities are provided.

Continuing to the Templeborough Works of the United Strip and Bar Mills, members saw an excellent example of continuous-mill practice for strip and bar.

The output capacity of this mill is 1,500 tons a week. 1,000,000 ft. of strip have been rolled in a period of 8 hours. The strip material is supplied in lengths or coils for the cold-rolling trade, for deep drawing and stamping, for all classes of tube manufacture, and for steel strip for electric cable armouring, also for baling strip.

The bar mill, which was then visited, has special cooling beds which allow lengths of bar up to 300 ft. to be handled, and that are straight without the need for after processes. The mill produces rounds, squares, flats, hexagons, and spring-steel bars in many qualities. The cooling provision is such that the material is not deformed whilst hot, and damage by cold-straightening is avoided, the bar being manipulated on a cooling bed by automatic toggle movements until it arrives on live rollers for conveyance to the shears.

The diversity of operations and equipment, and the layout of the grouped plants, proved specially interesting to visiting members.

Walker and Hall Ltd.

THE firm was founded nearly 100 years ago by Mr. George Walker, and has grown to its present size and scope from a small works on a portion of the present site in Howard Street. Mr. Walker, from his researches with a Dr. Wright, developed the process which has been the basis of modern methods of electro-plating. Soon after Mr. Walker was joined by Mr. Henry Hall, and in 1892 Messrs. Walker and Hall purchased the well-known business of Henry Wilkinson and Co., a firm commanding respect for the quality of their sterling silver, Sheffield plate, and electro-plated wares.

The present business, of which Col. Sir Albert Bingham, Bart., O.B.E., V.D., T.D., J.P., is governing director, has its works and showroom in Sheffield, 15 branch showrooms in the British Isles and overseas, and stores in Australia, New Zealand and South Africa. It is self-contained and self-supporting, making its own cutlery cases, cabinets, showcases, canteens, etc., with an engineers' shop working on improvements for the machinery of the business and making tools and dies, manufacturing a considerable quantity of metal and also manufacturing its own plate-cleaning material.

The firm originally practised electro-plating in gold and silver of metal goods for the Sheffield trades, but this was soon augmented by the manufacture of gold and silver wares and cutlery, whilst silver cups, trophies, statuettes and replicas are produced.

Naturally, much interest was shown in the various plating shops where articles of base metals are plated with silver or gold and the vats in which copper reproductions are made. The visitors were then shown the spoon and fork stamping shops, spoons being seen in course of manu-

Nickel-silver ingot casters at Walker and Hall's.

facture. This was followed by inspection of the ingot casting bays where nickel-silver ingots were being poured, and, in logical sequence, the press shop was visited. Here, heavy presses were drawing out the bodies of many different kinds of utensils including teapots, jugs, coffee pots, cream jugs, entrée dishes, etc.

Much interest was shown in the blade forging shop for cutlery drop stamping from red hot steel bars and the forging of the tangs of knives. These knives and tangs are hardened and annealed in small modern furnaces, blades are hand ground.

After having seen cutlery forging, the cutler's shop was next visited, and much interest was taken in the benches of operators doing hand work on table knives.

A long bay is devoted to spoon and fork buffing with a double row of operators working at belt driven buffing wheels. A big output and high quality of work were evident.

As was expected, the silver- and hollow-ware warehouses occupy a very large area, providing an imposing display of finished goods of all shapes and sizes and showing the diversity of plated-ware manufactured by this company.

In the art department, visitors saw where and how new designs are created and how the product is visualised, committed to paper, revised or approved and then put into production via the sequences of metal casting, forging, plating, buffing, etc., as seen during the tour of the shops.

Next to be visited was the cutlery warehouse, complete with almost every kind of table and other knives. The method of etching the blades was shown and finally the silver- and electro-plate showrooms were inspected. The rows of showcases and cabinets contained something to interest all, and much time was spent inspecting and admiring these finished products. The showroom is well laid out and effectively lighted, it being evident that the company realise that they understand the art of good display, appreciating the sales angle to emphasi e and make even more widely known the quality of their products.

Brown Bayley's Steel Works Ltd.

FOUNDED in 1870, Brown Bayley's Steel Works now cover an area of some thirty acres. In the early period of the Work's history, the products were Bessemer steel, converted bar and shear steel, and wrought iron. From the Bessemer steel, rails, springs, railway tyres and other products were made, the two rail mills at that time being among the most important in the country. It is noteworthy

Extension to West End of No. 1 Mill Buildings, looking west, at Brown Bayley's Works.

that a sample of the first Bessemer steel made is still in existence; it has the following composition :—

C	Si	M	S	P
0·31	0·04	0·40	0·130	0·106

From the inception of these Works there has been steady progress. In a relatively short time the production of open-hearth steel was begun, the first furnace being built on a site adjoining the converters. This furnace was dismantled in the early nineties and was succeeded by three "Batho" type furnaces which were built on a site previously occupied by the puddling furnaces and forge. These Batho furnaces are still in operation and the visitors were able to inspect them and to note with interest the shape of the hearth and the accessibility of the regenerators and connecting flues.

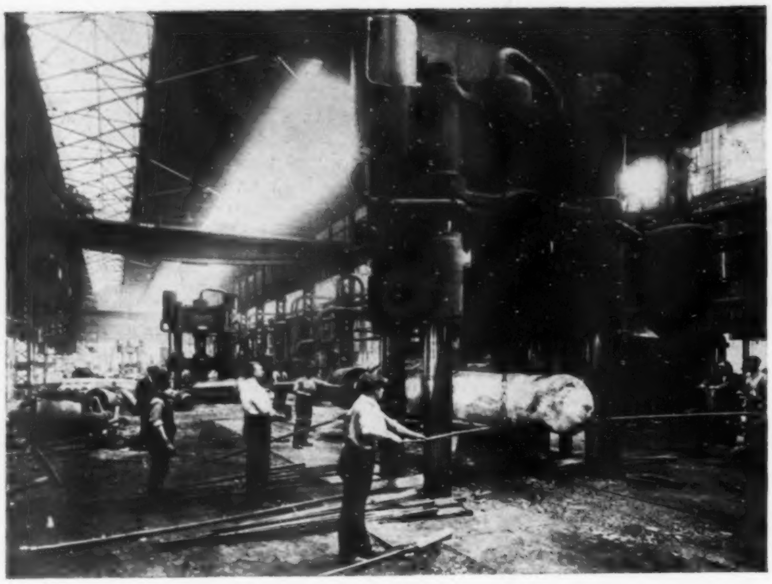
In those early days scientific control, as we know it to-day, was unknown, but a chemical laboratory was built soon after 1873, and it was in this laboratory that John Oliver Arnold—who afterwards became Professor of Metallurgy at what is now the Technical Department of Sheffield University—came as a youth of twenty to learn steel making. He remained at the works for about ten years and some of the "standard bars" for the determination of "carbon by colour," which he prepared while at the works, are still preserved in the works laboratory. Before 1888, crucible furnaces had been built and also a well-equipped testing house, the latter containing one of the earliest Buckton single-lever testing machines worked by man-power.

A further step in developing scientific control was taken in 1904, when a research department was founded—appropriately enough by one of Professor Arnold's students—and was housed temporarily in an old shed in the works until the new research laboratory was ready for occupation about the middle of 1905. During the next few years, the works extended considerably. A 1,200-ton hydraulic press—built by Davy Bros.—was put down towards the end of

One of the plating shops at Walker and Hall's.

1905 and of the Newhall open-hearth plant—on the north side of the works—was commenced in 1907. Further ground having been acquired towards the south-west corner, the present offices were erected about 1909. A feature of this period (1905-1910) was also the increasing production of high-tensile railway and tramway tyres. The necessity for heat-treating these, and the demand for heat-treated railway axles, led to considerable extensions in the heat-treatment department.

Another epoch in the firm's history occurred in 1915, when, to the Bessemer and open-hearth methods of steel production was added the electric arc furnace and also a completely new product—stainless steel. The latter will always be associated with the name of Mr. Harry Brearley, whose services with Brown Bayley's Steel Works, Ltd., date from 1915, first as works manager and later as technical director. Largely as a result of Mr. Brearley's direction, the company began to produce alloy steels on a large scale, their product previously having been mainly, though not entirely, carbon steels. Considerable extensions followed, partly owing to war-time demands.



Heavy Forgings Press Shop at Hadfield's East Hecla Works.

During this latter period, the design of coal-fired heating furnaces was studied intensively. As a result, a new design of furnace was introduced and patented which not only cut down coal consumption very considerably but also reduced to an almost negligible amount, the emission of thick black smoke. In the last few years, there have been many further improvements and additions. In 1929, forging and upsetting machines were put down to meet the growing demand for motor vehicle axles, and other similar forged articles of special steels, and their number has since been increased. An electrically driven sheet mill was installed in 1931 for rolling stainless and heat-resisting steel sheets and, shortly afterwards, a modern strip mill for producing stainless steel strip. Polishing shops for dealing with this sheet and strip have been built and are among the best-equipped in the country. The old No. 2 mill (converted from one of the old rail mills) was dismantled but No. 1 mill, the billet mill, has been rebuilt, modernised, and equipped with electric drive in place of the old steam engine. To the 7-ton electric arc furnace originally installed has been added a 8/10-ton furnace and a further 15/20-ton furnace is now under construction. The old No. 3 mill—producing spring bars of all shapes—has been completely rebuilt and re-engined; like the other mills it is now electrically driven. Altogether these works provided ample evidence of that progressiveness which has characterised the firm of Brown Bayley since its inception.

Hadfields Ltd.

THE works included in this visit embraced the East Hecla and Hecla Works, and although the products are well-known to those who participated, the opportunity to see the plant and operations used in their production was welcomed. Like many of Sheffield's pioneer firms, Hadfields Ltd. was founded about the middle of last century. The Company began its career by manufacturing steel castings, and for the first few years its activities were confined exclusively to this work. Co-existent with its growth the field of operations was extended, and now, in addition to being perhaps the largest makers of steel castings in England, large scale operations are carried out in the works in the production of steel forgings, rolled products in all classes of high grade steels, crushing and dredging machinery, railway and tramway rail track, and mining requisites of every description.

One of the outstanding events in the history of this firm was the invention, about half a century ago, of manganese steel by the present Chairman of the Company, Sir Robert Hadfield, Bt., F.R.S. The advent of this special steel was the commencement of a new era in metallurgical research, and its introduction was without doubt one of the chief determining factors which led to the development of the modern alloy steel. From the first this special steel was found to withstand abrasion better than any other alloy. Known as "ERA" manganese steel it is universally employed for the wearing parts of stone breaking, ore crushing, and dredging machinery, and is unequalled for points, crossings, curves, and other special work for tramways and railways.

The steel foundries cover an area of nearly 12 acres and are claimed to be the most extensive of their kind in the world. The main building has a length of over 1,000 feet and is equipped with the latest types of moulding machines, jolt rammers and other labour-saving machinery. Every square foot of the moulding area can be reached by one or more of the numerous overhead electric cranes with which the various bays are equipped.

The machine shops, of which there are several, are equipped with machine tools of the most modern types, including self-contained electrically-driven planers, boring mills, milling machines, and lathes capable of dealing with the largest castings and forgings, and of accommodating hydraulic cylinders up to 30 ft. in length. As occasion demands, modern machine tools are continually being installed to replace older types. One of the bays of the machine shop, devoted mainly to the machining of marine shafting and other large forgings, is illustrated. This shop also contains the latest types of precision grinding machines which are used for grinding and finishing high-grade hardened steel rolls used for cold rolling steel, brass, copper, and other metals. In the machine shops and in others adjoining them, the erection of dredging and crushing machinery, the assembly of tramway and railway track-work, and fitting up of other structures, are carried out and finally tested where this is necessary.

In the forging shops visited, there are twenty-eight steam and pneumatic hammers ranging in size from $2\frac{1}{2}$ cwt. to 4 tons, and twenty-five hydraulic presses from 60 to 2,000 tons capacity. The accompanying view shows one of the heavy forgings press shops which contain three vertical quick acting hydraulic presses, two of 1,500 tons capacity and one of 1,000 tons. Forgings of large diameter

One of the large machine shops at Hadfield's Works.

and great length are executed in this shop, including large crushing roll shells and marine shafts.

The rolling mill buildings occupy an area of about five acres in which there are three mills of different size. They are all electrically driven, the largest being a reversing 28 in. blooming and finishing mill. This large mill when running continuously has an output capacity of 1,500 tons a week, handling ingots weighing $1\frac{1}{2}$ tons each and rolling them down to billets as small as $2\frac{1}{4}$ in. All classes of special steels, also rails of the heaviest section in "ERA" manganese steel, are rolled in this mill. The other two mills are 14 in. and 11 in. bar mills, and are employed for rolling billets of both carbon and alloy steels to the various commercial sizes and sections, also for the production of high-speed tool steels, mining drill steels, also turbine blading in special "Hecla ATV" steel.

Several shops are devoted to the production of requisites for collieries and mines, in which are manufactured tub controllers, automatic runaway tub arresters, tub greasers, prop withdrawers, rope haulage pulleys and frames, rollers and boxes, and articles of similar character. One building is furnished with machines of special design and used exclusively for fitting colliery wagon wheels on axles, and two others are fitted up with the necessary power driven tools for manufacturing mine wagons and colliery tubs complete, in both wood and steel.

Mellowes and Co. Ltd.

THIS company are patentees of the "Mellozing" process of metal spraying, and, in view of the rapid progress of metal-spraying processes, the members were particularly impressed by the process in operation at these works. Here it is used for spraying coatings of zinc to steel casements, which are a speciality of Mellowes and Co., Ltd., and also for carrying out contract metal spraying. The process is not new, but a brief description will be of interest.

All metal surfaces are thoroughly cleaned by sandblasting before "Mellozing," to remove all traces of rust, scale and oxide; this also provides a key surface which ensures a firm adherence of the sprayed coating. The metal to be sprayed is first melted in a small crucible from which the container of the pistol is filled; a bunsen flame under this container, the gas for which is obtained by connecting the pistol to the ordinary gas mains by means of a rubber hose, keeps the metal in a molten condition whilst spraying.

The pistol is also connected by a rubber hose to a compressed air supply of 60 to 75 lb. per sq. in., and when the molten metal flows to the nozzle it meets the pre-heated compressed air, which very finely atomises it, so that minute particles of metal are blown against the surface, being covered at a tremendous velocity, and adhere firmly, forming a continuous metallic coating to the fine matte finish. The thickness of this coating is approximately 0·005 in., but this coating can be increased to any desired thickness. The principal use for "Mellozing" is as a means of combating corrosion of iron and steel, and for this purpose zinc is most generally used, owing to its high corrosion resistant properties and its comparatively low cost.

The visitors were also able to see at Langsett Road Works the fabrication of metal windows, and observed this throughout its various operations, commencing with the stretching and machining of the various steel sections employed in this manufacture, thence to the fitting shops, where all the component parts are assembled, and then finally to the assembly of the various units and the attachment of the fittings. Thus, they were able to examine this special work in progress, and on completion various types of metal sashes for industrial, domestic, and public contracts now running.

The lantern light works also proved of great interest, and similar facilities were provided for the examination of lantern and roof-light structures of many and varied designs, and the party followed the various operations of this class of manufacture very closely. The Corporation Street Works were the next to be visited. Here members were shown the process of the manufacture of the firm's "Eclipse" patent system of roof glazing, which is extensively used. The process of extruding lead pipes also proved of considerable interest, large quantities of which are manufactured yearly. The drawing of the lead cover, which is used to enclose the steel bar in connection with "Eclipse" glazing, attracted much attention.

English Steel Corporation Ltd.

FOUNDED in 1929 by the rationalising scheme which linked up the steel interests of Vickers Ltd., at Sheffield, with those of Armstrong-Whitworth, at Openshaw, Manchester, and later, those of Cammell Laird at Sheffield and Penistone, the English Steel Corporation Ltd., has carried out considerable extensions and members of the Institute forming the party visiting the Vickers Works were able to see the results of extensive reorganisation and plant and equipment of a very modern character.

Although some of the visitors only had time for a very brief view of the metallurgical and research department, some idea of the scope of work which it embraces will be of interest. Primarily, its purpose is to study, observe, and, when necessary, to supervise all metallurgical operations carried out within the several works of the Corporation,

Metal spraying steel casements at Mellowes' Works.

Coating a steel tank by the "Mellozing" process.

but other important functions are incorporated in the duties of this department. It will advise the manufacturing, estimating, and sales departments on technical problems regarding metallurgical processes, properties of materials, and the selection of steels for specific purposes; metallographic investigations of materials in course of production, or of parts returned from service for "post-mortem" examination, when either good or inferior performance demands; determine any chemical analysis of raw materials or of steel in course of manufacture, required either for purposes of control, selection or investigation; determine or collect thermal, physical, mechanical, or other data required for the information of manufacturing departments, the service of customers, or the progress of research; and generally carry out research and investigations relating to the manufacture, properties, and improvement of steels.

To meet the rapidly extending fields of activity, in which steel plays so important a part, much concentrated effort and scientific knowledge are required and collaboration between the melting plant and the metallurgical and research department, characteristic of these works, facilitate progress and materially assist in the manufacture of the highest grades of carbon and alloy steels possessing reliable qualities. For this purpose, the most modern equipment has been installed in the various departments.

The attention of the visitors was directed more particularly to the acid open-hearth furnaces, the rolling mills and to the heavy forge and machine shops. The Siemens' department, completed about four years ago was a substantial contribution to the reorganisation scheme; it embodies the latest practice and provides facilities for making ingots of over 250 tons in weight. With this plant and the experience gained from over a century by the firms incorporated, the English Steel Corporation has been in a unique position, in a rapidly expanding market, for the manufacture of all the special steels required, not only by its customers, but also by the various departments in Vickers' Works, where it manufactures large hollow forged steel vessels, weighing over 160 tons, for use in chemical and oil engineering processes and power plants under conditions of high temperature and pressure; forgings, such as marine crankshafts, propeller shafts, high-speed electrical rotors, locomotive crank-axles, etc.; drop forgings for automobile, aircraft, and general engineering, such as the crankshafts and other important parts supplied by this firm for high-speed machines, tyres, axles and springs for railway and tramway rolling stock, springs and frames for road-vehicles; and a wide range of other steel products.

From the Siemens' department the visitors were taken to the forge and heat-treatment departments. Both these have recently been rebuilt and re-equipped with the object of centralising the work to be carried out. In addition to many other presses, the forge is equipped with a 7,000-ton press which is claimed to be the largest in the world to be operated by a high-pressure electro-hydraulic pumping set; here the visitors were able to see the forging of locomotive crank-axles, line shafting, and huge hollow forged vessels.

The visitors proceeded through the carbonising plant to the south machine shop, the latter being one of the largest in this country. It has recently been modernised and to-day it is well-equipped with modern machines which can deal with forgings covering a range from a few pounds to well over 250 tons in weight. Some idea of the size of the various machine shops at these works may be gathered from the fact that the combined length of all the bays is just under two miles.

The drop-forging department, also included in the visit, is also very extensive and is one of the most modern in the country. Over 350 tons of drop forgings are manufactured per week for leading aircraft, automobile and commercial vehicle manufacturers.

These works are very extensive, covering about 169 acres, and it was only possible in the time available for the visitors to inspect a few of the departments, but it may be mentioned that other activities of the Corporation include the manufacture of steel in the form of billets, bloom, bars and sheets; tyres, axles, springs; engineers' small tools; files, hacksaws and magnets. Since the commencement of the scheme of reconstruction and modernisation the Corporation has spent over £2,000,000 in extensions and new installations and further extension schemes are in progress.

Withdrawing from a reheating furnace a partly forged converter body at the works of English Steel Corporation, Ltd.

Edgar Allen and Co. Ltd.

FORMED nearly sixty years ago, the firm of Edgar Allen and Co., Ltd., may be regarded as one of the most progressive of the noteworthy Sheffield manufacturers. Since its inception, this firm has been concerned with quality production, and has consistently developed its plant and technique to maintain high-quality production on economic lines. It is noteworthy, for instance, that this firm was the first in the world to make steel castings by the Tropenas acid process, the first in this country to install for commercial production an Heroult electric arc furnace, and the first in the world to make use of the high-frequency electric furnace for steel manufacture. Thus, it may be stated, that those members who visited

these works did so at the invitation of a firm possessed of that courage and enterprise which earned a position amongst the pioneers of Sheffield's steel industry.

The products of Edgar Allen and Co., cover a very wide range ; broadly, they may be classified under tool steels, steel castings, tools, circular and stone saws, magnets, trackwork, and various types of crushing and grinding machinery. Particular attention was given to the manufacture of special steels in the high-frequency electric furnaces, of which there are four. Tool steel, magnet steel, heat-resisting steel, and many other grades of special quality steels are made in these furnaces. Of particular interest in tool production was the electric welding process by which the problem of satisfactorily securing the high-speed steel ends to mild steel shanks has been solved.

One of the departments which proved of special interest to the visitors was the steel foundry. Here the castings produced are of great variety, production being concerned not only with the demands from the machinery departments of these works, but with the increasing need for alloy steel castings by other firms. The demand for steel castings to meet special requirements has substantially increased in recent years and the foundry has been extended. Some indication of its size is obtained from the fact that the average production is about 300 tons per week, which includes a range from small repetition castings to those of 30 tons each. The foundry is well equipped and thoroughly modern, the moulds for repetition castings are prepared by machines but the larger work is dependent upon craftsmen possessing skill of a high order. The casting bay is equipped with Tropenas converters and the Heroult electric arc furnace, the latter being devoted largely to the making of manganese steel for parts in crushing machinery and for rail tracks, both of which are specialities of this firm.

Adjoining the foundry are the cleaning, fettling and finishing shops. Modern plant is installed for shot-blasting the castings, which is very effective in producing clean surfaces. Annealing furnaces operated under close control are installed in one of these departments to relieve the castings from internal strains, and in an adjacent shop, machinery is installed so that castings can be given their finished dimensions.

Considerable interest was shown by the visitors in the variety of crushing, grinding, screening, conveying and drying machinery both finished, ready for despatch, and in course of construction. These machines, with which Edgar Allen's name is associated throughout the world, are specially designed and constructed for dealing with all kinds of materials, under the most adverse conditions, from the crushing and screening of various ores to the most modern machines now employed in road engineering. Heavy service conditions invariably necessitate that parts of these machines, those subject to excessive wear, must be made of special steel, and manganese steel plays a prominent part in maintaining the record for service these machines possess. This type of machinery is built in a separate department, which possesses its own machinery shop, fitting and erecting sections.

It has only been possible to refer briefly to some of the products of this firm, mention, however, may be made of machinery of an auxiliary character, such as conveyers, elevators, screens, storage hoppers and bins, which are also manufactured. To the casual observer an outstanding feature about these works seemed to be a desire to maintain the high reputation, which Edgar Allen's products have earned for themselves in the past and which, judging from the orders in hand, is meeting with considerable success.

Thos. Firth and John Brown Ltd.

ONE of the most interesting visits associated with this meeting was that to the works of Thos. Firth and John Brown Ltd. The great extent of these works made it impossible to visit all the different departments in the limited time at the disposal of the visitors, but sufficient

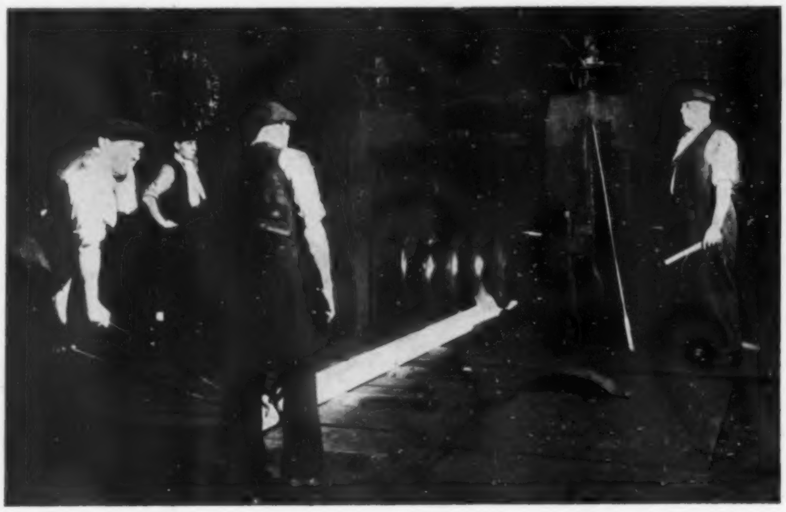
Rough machining large hollow-forged vessel on a 55-in. centre lathe at the Vickers' Works of English Steel Corporation.

was inspected to indicate that this firm is one of the foremost manufacturers of high grade carbon and alloy steels, in finished and semi-finished forms, in this country. Much care is exercised in maintaining a high quality of product. Such manufactures as rust-, acid-, and heat-resisting steels, tool steels, spring steels, file steels, high-tensile steels, non-magnetic steels, magnet steels, steels of high coefficient of expansion, case-hardening steels, nitriding and special steels generally, necessitate scientific and technical consideration. For this purpose the Brown-Firth Research Laboratories are in intimate contact with the various departments.

Although primarily designed for the influence they undoubtedly bring to bear on the process and products of the associated companies, these laboratories are unhesitatingly placed at the disposal of manufacturing concerns which are utilising this firm's steels for the purpose of assisting in the solution of consumer's own problems. Actually these laboratories were visited after various

Light-plating section of one of the machine departments at Edgar Allen's.

Electric-welding twist drill shanks at Edgar Allen's.



One of the mills in operation at the works of Firth-Brown.

sections of the works had been inspected and formed a fitting conclusion to an interesting and informative afternoon.

The large battery of electric arc melting furnaces, comprising a 30-ton, a 15-ton and two 10-ton furnaces, proved of great interest. Two of these, each with a heat of nickel-chromium steel, were tapped and the steel cast into ingots. High-grade forgings are only produced by commencing with the finest quality steel, melted and cast under careful technical control. Normally the steel is manufactured from specially selected pig-iron and scrap in the acid open-hearth furnaces. In special cases, however, involving the more onerous conditions of service, these electric furnaces may be used to make ingots up to 60 tons in weight. The electric furnace process provides better facilities for deoxidation of the bath, and yields a steel very free from non-metallic inclusions. Further melts were sun-cast—from a 1-ton and 5-ton high-frequency electric furnaces, the latter having only recently been installed. The steels produced in these instances were two grades of the well-known "Staybrite."

Passing through the electric melting shop the visitors spent some time in the large new tool shop, where the small tools, for which this firm has a high reputation, are manufactured. The large number of operations in the manufacture of even the smallest drill and the careful inspection of each one to ensure that only perfect drills are marketed came as a surprise to the majority of the visitors. Another feature of outstanding interest in this department was the cutting of a 5-in. diameter bar of 35-ton steel by an "Insto" saw. The cut was made in about one minute and it seemed to generate very little heat in doing so.

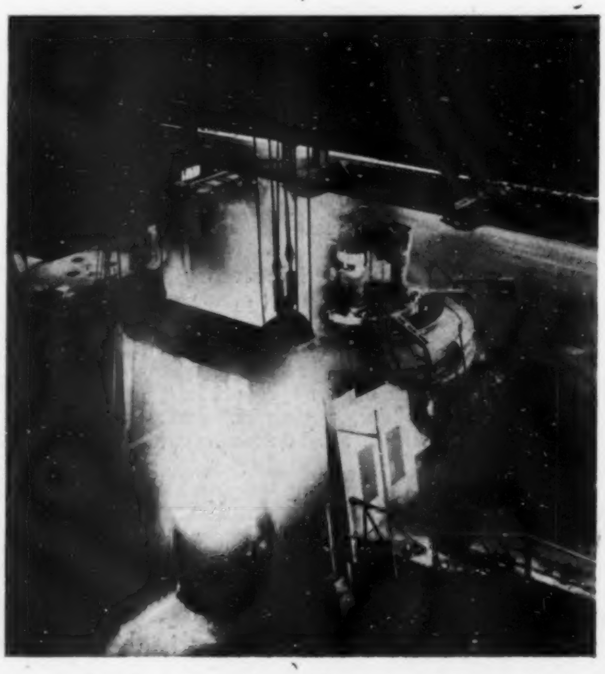
The machine department for giving the final shape to large forgings was the next to be visited. Here was seen some of the products of this firm being machined, including propeller shafts, large pressure vessels, large built-up marine steam reciprocating engine crankshafts, solid forged turbine rotor shafts, hollow forged seamless boiler drums, several large forgings in processs of completion for the sister ship to the *Queen Mary*, now being built at the shipbuilding yard of Messrs. John Brown and Co. Ltd., Clydebank, including large rims for the reduction gearing, and a very large range of other important parts for which forgings in suitable steel give the best performance in service.

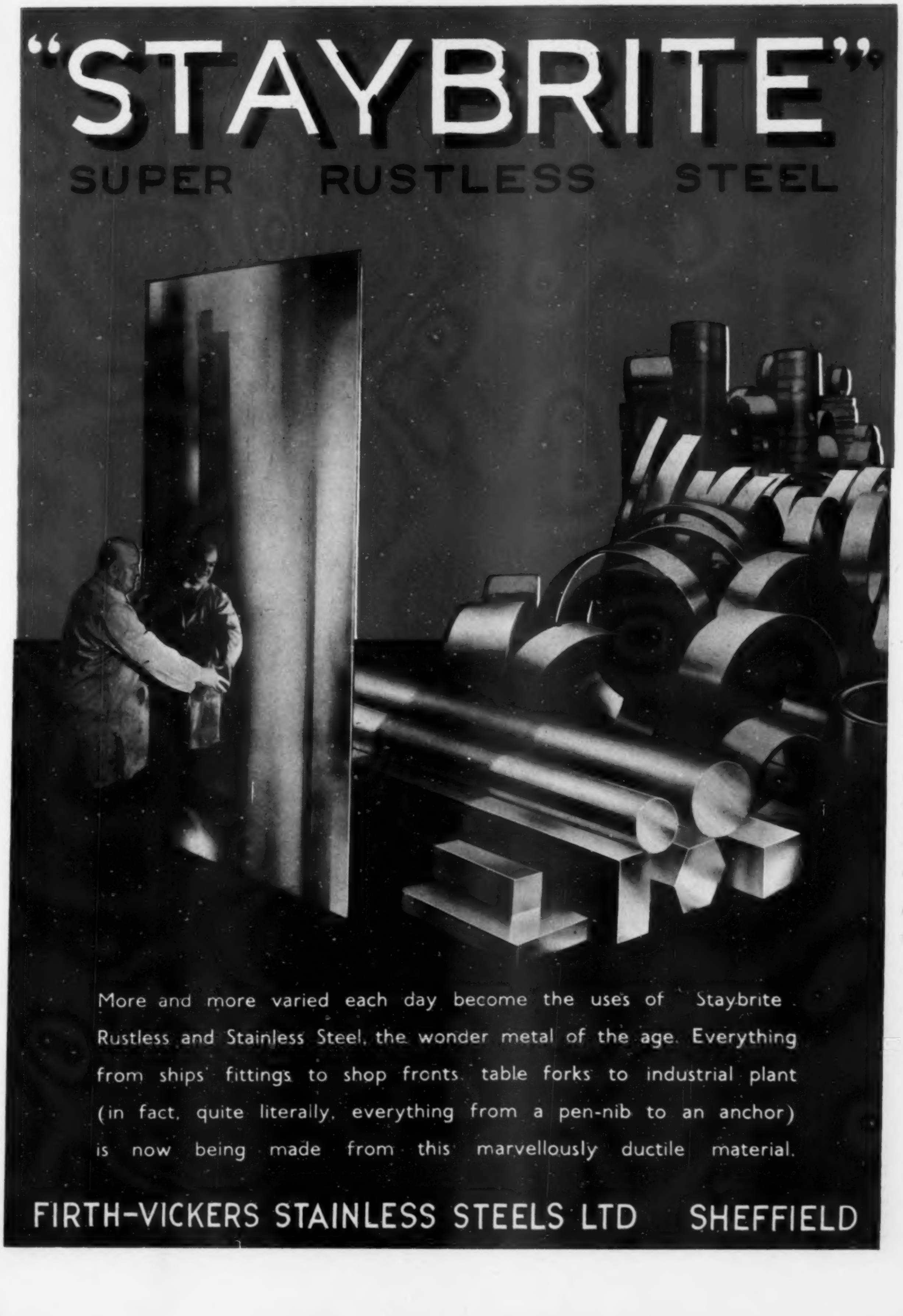
The forging operations involved for these large pieces have only been possible as a result of developments of the forging press. The spectacle of seeing a plant at work which can shape masses of steel several feet in diameter by exerting a continuous squeeze of 6,000 tons or more together with the auxiliary cranes, rotating gear and other tools, will long be remembered by the members who formed this party of visitors. In addition to this large press the company possesses a well-equipped range of heavy hammers, together with adequate punching and drawing presses, and the largest hollow rolling mill in the world. The reheating furnaces to bring the metal to the required forging temperature are of special design, and the heating is controlled not only as regards temperature, but also speed of heating, time of soaking and nature of furnace atmosphere, and the support during heating.

Following the works visit a film was shown and a descriptive talk given by Dr. W. H. Hatfield, which were followed with interest by all the visitors. Dr. Hatfield said it had been impossible to show all the various departments and the film showing various processes in the manufacture of rust-, acid-, and heat-resisting alloys would be useful since it would only occupy about 10 minutes. The film presented

(*Continued on page* 187)

Tapping one of the electric melting furnaces at Firth Brown's.




"STAYBRITE"
SUPER RUSTLESS STEEL
More and more varied each day become the uses of "Staybrite" Rustless and Stainless Steel, the wonder metal of the age. Everything from ships' fittings to shop fronts, table forks to industrial plant (in fact, quite literally, everything from a pen-nib to an anchor) is now being made from this marvellously ductile material.
FIRTH-VICKERS STAINLESS STEELS LTD SHEFFIELD

IRON AND STEEL INSTITUTE

Autumn Meeting at Middlesbrough

Middlesbrough and the district has been responsible for a number of successful annual meetings of the Iron and Steel Institute, and this one, held on September 14–17, was no exception to the rule. In this article a brief summary of the proceedings is given, together with a digest of the reports and papers presented, for the introduction to which we are indebted to the President, Mr. Alfred Hutchinson, M.A., B.Sc.

THE autumn meeting of the Iron and Steel Institute was held in Middlesbrough, and the arrangements included visits to various works in the district. This is the fourth visit of the Iron and Steel Institute to the district. It first visited the district in 1869, shortly after its formation, in the proposals for which prominent Middlesbrough ironmasters had taken an active part. In that year it was under the presidency of William, the seventh Duke of Devonshire, and the members then saw a fully developed pig iron industry, following the discovery of ironstone in the Eston Hills. The next visit took place in 1883, at a time when great interest was being displayed in the then recently discovered basic Bessemer process.

Alfred Hutchinson

In the history of metallurgical inventions and applications, one of the chief landmarks was the discovery of the basic Bessemer process, and the Cleveland district can claim the distinction that it was there in the works of Messrs. Bolckow, Vaughan and Co., Ltd., that the final experiments were carried out which proved to the metallurgical world that ordinary qualities of steel could be successfully made from phosphoretic ores, such as were mined in Cleveland. This discovery led to the development in the manufacture of steel from phosphoretic ores all over the world, and more particularly in the Lorraine and Luxemburg districts. Thus, Cleveland has the distinction of being the place in which the possibility of this huge development in industry took place, and our members have had an opportunity to visit the district in which the foundations of world-wide steel developments were laid.

Between the second and third visits of the Iron and Steel Institute to the district, still further developments had taken place by the establishment of the basic open-hearth process, and gradually there had been developed large plants for the production of steel products, so largely used in the shipbuilding and engineering trades.

Between the last visit and the present visit of the Institute still further developments have taken place, and among those plants which members were invited to see the following may be mentioned as of special interest :—

(1) The building and equipment of the Redcar Works of Messrs. Dorman, Long and Co., Ltd., which was in the first instance a war measure for the production of plates.

(2) The large extensions and works reorganisations at the Cleveland Works of Messrs. Dorman, Long and Co., Ltd., originally Messrs. Bolckow, Vaughan and Co., Ltd., in which two modern and up-to-date batteries of coke-ovens have been built, with an important scheme of distribution of surplus gas from the coke-ovens and blast-furnaces. The coke-oven gas is used partly as the town supply for domestic use, and partly for heating the steel furnaces and other parts of the steelworks plant which had previously been heated by gases made from coal gasified in producers. Further, a complete mill equipment with a cogging mill, and a new 14 in. mill of the most modern construction.

(3) At the Cargo Fleet Works, too, development and progress has been continuous. Amongst some of the latest, I may mention the installation of a continuous reheating furnace for heating cold ingots to a temperature at which they can be transferred direct to the soaking pits, previously to being rolled in the mills. At these works also will be seen a new continuous mill for rolling strip and a great variety of steel products, the most up-to-date mill of its kind in the country. The Cargo Fleet Works is the home of the tilting furnace, in the development of which particular form of steel furnace Mr. Benjamin Talbot has played so great a part.

(4) At the Malleable Works of the South Durham Iron and Steel Co., Ltd., members had an opportunity of inspecting their steel pipe works.

(5) The Skinningrove Works, which are situated on a minefield, drawing their supplies of native ores direct from the adjoining Loftus Ironstone Mine. There those ores are converted direct into finished steel. The pig iron produced in the blast-furnaces being converted into steel ingots in a modern plant consisting of tilting furnaces. The steel ingots are rolled direct into finished products. Recently an 18 in. mill of modern design, built by a British firm, has been put into operation most successfully, and is well worthy of inspection.

In addition to the steel-making industry in the district, members have had the opportunity, by kind permission of the Imperial Chemical Industries, Ltd., of seeing the magnificent works in which this company are carrying out research work on experimental scale for the production of petrol from coal, which it is hoped will prove a great national asset in the future.

Since the last visit, a new generation has arisen, and this meeting has afforded an opportunity to many of the

younger members of the Institute, who do not know the North-East Coast of Yorkshire and the wonderful moorland scenery of this district, to make acquaintance with its beauties at the time the heather was out in full flower and the district at its very best. Special visits were made to Rievaulx Abbey, and garden parties arranged at Mr. Benjamin Talbot's home, Solberge Hall, and Sir Maurice Bell's delightful home, Mount Grace Priory.

The intitial meeting was held at the Cleveland Technical Institute, and owing to the indisposition of Mr. Benjamin Talbot, chairman of the Reception Committee, Mr. Arthur Dorman, vice-chairman, presided. The Mayor of Middlesbrough, Councillor George Carter, who was accompanied by the Mayoress, extended a very hearty welcome to the members of the Institute, their wives and lady friends, attending the meeting, on behalf of the Corporation and citizens of the town.

Middlesbrough, as an industrial town, he continued, has always been in the forefront of progress in matters relating to the iron and steel industry, and he recalled with satisfaction that some of the great pioneers of the industry were Middlesbrough men, and have occupied the premier position of the Institute; he referred to Sir Lowthian Bell, Sir Bernhard Samuelson, Mr. H. W. Richards, Sir Hugh Bell, Dr. Arthur Cooper, Mr. Francis Samuelson, Dr. John E. Stead, and Mr. Benjamin Talbot, while the present President, Mr. A. Hutchinson, is a also Middlesbrough man.

In replying to the welcome, Mr. Dorman stated that, since the last visit of the Institute to Middlesbrough, the basic open-hearth process had, to a great extent, gradually superseded the acid open-hearth process. His father, then Mr. A. J. Dorman, accelerated this change-over at the Britannia Works of Dorman Long and Co., and, in conjunction with the late Sir Hugh Bell, built the Clarence Steelworks for the special purpose of making steel from Cleveland pig-iron. The Talbot process was then becoming a power in the land, and the large tilting furnaces overcame some of the difficulties then experienced in making steel from Cleveland iron.

After expressing regret at the absence of Mr. Talbot, through illness, Mr. Dorman, on behalf of the Reception Committee of the Institute, thanked the Mayor and Corporation for the ready help given to the Institute. Mr. Hutchinson, the President, also expressed thanks for the warm welcome Middlesbrough had accorded members and their friends.

Business Sessions

With the conclusion of the civic proceedings, Mr. Hutchinson took the chair for the business proceedings. Reference was made to the late Dr. Masaryk and Mr. John Hodge, and the assembly stood in silence as a mark of respect. It was subsequently announced that the Earl of Dudley had been nominated for election as president at the annual meeting to be held on May 4 to 6, 1938. At this meeting two days will be devoted to a symposium in steelmaking, with special reference to the open-hearth practice. Mr. Hutchinson also announced that an invitation from the American Institute of Mining and Metallurgical Engineers and the American Iron and Steel Institute to hold the 1938 autumn meeting in America, jointly with the Institute of Metals, had been accepted.

The meeting then proceeded to matters of a technical character, the first being a special report of investigation on a blast-furnace, smelting principally Lincolnshire ores, at the Appleby-Frodingham Steel Co. Ltd. This report, which had been prepared by a blast-furnace reactions sub-committee of the Iron and Steel Industrial Research Council, was presented by Professor W. A. Bone. The results of the research pointed out how greater efficiency could be obtained in blast-furnace operation. The Thomas-Gilchrist basic process from 1879 to 1937 was the subject of a paper presented by Mr. F. W. Harbord, while hot-metal practice in five melting shops on the North East Coast was presented by Mr. W. Geary. These and other reports and papers are briefly summarised.

SOME EXPERIMENTS IN A SMALL-SCALE CUPOLA

Following on the pioneer work of the American Bureau of Mines on the combustion of lump coke at high temperatures and at rates comparable with those in the blast furnace hearth, other workers have investigated the high temperature combustion of lump coke on a reduced scale as a direct method of studying the factors operative in industrial practice. This paper by Messrs. H. E. Blayden, W. Noble and Prof. H. L. Riley describes experiments of a similar character. Efforts have been made to imitate, on a reduced scale, the conditions prevailing in the full-scale cupola, and, under these conditions to compare the performances of a variety of full-scale and experimental oven cokes, and such different forms of carbon as electrodes and retort carbon, carbonised anthracite, gas coke, petroleum coke, etc.

The experiments show that the feasibility of melting iron on a small scale under controlled conditions suggests interesting possibilities of the small-scale cupola as a stand-by for occasional small castings, irrespective of its application for research purposes. The performances of some commercial and experimental oven cokes and several carbons have been compared under similar operating conditions in a cupola possessing a shaft of 9 in. internal diameter which gave a melting rate of 220-250 lbs. per hour of iron at about 1,330° C.

It is shown that the coke size and rate of air blast have a marked influence on both the rates of combustion and melting; metal temperatures appear to be more sensitive to variation in the coke size than to variation in the air blast above certain limits, and these are probably determined by the dimensions and design of the cupola. It would appear that the area and time of contact of the coke and air, the coke size and rate of air supply, are the predominating factors during combustion.

The results obtained tend to support the opinion that the hearth temperatures obtained in cupola operation, and probably also in blast furnace practice, are more affected by differences in the mechanical strength of cokes than by differences in coke reactivity. But the differences in coke reactivity might become effective under certain conditions, as is suggested by the higher hearth temperatures observed with highly graphitised materials. It is interesting to note that the cupola performances of cokes made in an experimental oven from two normal Durham coking slacks and the same slacks blended with up to 30% of coke fines were similar under identical operating conditions. Another comparison which showed little effect on the cupola performances of the resultant experimental oven cokes was obtained from the blending of a normal Durham coking slack with 5% and 10% of crushed dry peat.

The experiments were carried out in the laboratory of the Northern Coke Research Committee at Newcastle-on-Tyne.

THE INFLUENCE OF CARBONISING CONDITIONS ON COKE PROPERTIES

Further work by Mr. H. E. Blayden, Mr. W. Noble and Prof. H. L. Riley, is described in this paper concerning two Northumberland "non-coking" coals which have been carbonised under mechanical pressures, ranging from 0·2 to 20 lbs. per sq. inch. The effect of coal size has also been studied with one of these coals. In this investigation the relative strength of the cokes prepared has been measured by a new apparatus, designed for the purpose, and the indices obtained show remarkably close correlation with other physical and chemical properties.

In certain cases the strength index of the coke was raised from zero to that given by metallurgical cokes, and increase in carbonisation pressure produced a pronounced increase in the strength of the resultant coke. The authors show that the effect of pressure on coke strength

is dependent upon coal size and grading, the coke strength decreasing with decrease in size at low pressures and increasing with decrease in size at higher pressures, in the case of the coal examined.

Coke formation is dependent on the assumption of some degree of softening or fluidity of the coal particles during coking and with good coking coals this softening effect is appreciable even at slow rates of heating. During coke formation these softened particles tend to coalesce into a plastic mass, the cementation of the material is completed by solidification of the material into a continuous, porous coke structure. Pressure has a pronounced effect on the binding or cementing action, partly as a result of the deformation of the particles and partly by the increased area of contact.

Adequate pressures are usually produced by the generation of gaseous decomposition products in the plastic coal, in the case of coking coals, and these pressures are also influenced by such factors as the rate of heating and the density of packing of the particles, whilst the nature of the coal is at all times a significant factor.

But poorly-coking coals do not soften readily at slow rates of heating, the temperature range of plasticity is relatively small. But the fluidity has been shown to increase with high rates of heating. Slow rates of approximately 1° per minute are insufficient with some coals to cause cohesion of the particles except under the influence of pressure and which pressure the carbonisation process itself cannot provide. Maximum binding effects for the poorly-coking coals at slow rates of heating can only be obtained by the application of pressure.

Certain secondary effects were observed at high applied pressures when the swelling induced by the entrapped gases caused thinning of the cell walls and increased porosity. It may be that the cracking of the hydrocarbon vapours produced under pressure during the plastic stage, at the relatively high mechanical pressures used, also influenced the strength of the coke by creating greater binding effects; but this is a factor whose importance is difficult to assess although it may be an influential factor in the strength of the cokes prepared from finely crushed (<I.M.M. mesh) coal.

The results showed a close correlation between the figures obtained in the micro-strength tests and the other experimental data. It is evident that the strength indices have a fundamental significance in relation to the mechanical strength of the coke substance and the tests carried out provide useful supplementary data to those given by such existing tests as shatter and abrasion.

THE MECHANISM OF NITRIDE HARDENING

There has been some controversy about the effect of nitriding on the microstructure of Nitralloy steel. The general opinion is that it is mainly unaltered by the process, the only effect universally observed being that the ferrite matrix of the hardened case etches more rapidly than the core, forming a stained rim, the depth of which corresponds roughly to the thickness of the case. Some workers have observed a network of scattered needles of a white constituent in the outer part of the case, especially in samples annealed before nitriding and in the decarburised layer at the surface of hot-rolled bars. The widely-accepted explanation of the hardness of the case is that it is due to "dispersion" or "precipitation" hardening, caused by sub-microscopic particles of aluminium nitride and chromium nitride dispersed through the α-iron matrix of the steel. The main objects of the investigation described in this paper by Dr. M. S. Fisher and Mr. Z. Shaw were (*a*) to test the above hypothesis, (*b*) to find whether iron nitride is a normal constituent of nitrided steel, (*c*) to study the mechanism of nitriding, and (*d*) to find whether the process could be speeded up by modifying the nitriding conditions, particularly by some preliminary treatment of the surface of the steel.

Two Nitralloy steels of the following composition were used, the essential difference being in carbon content: Steel C3: 0·28% C, 1·08% Al, 1·60% Cr, 0·41% Mo, 0·25% Ni, 0·35% Si, and 0·65% Mn. Steel C5: 0·53% C, 1·36% Al, 1·67% Cr, 0·29% Mo, 0·25% Ni, 0·24% Si, and 0·68% Mn.

Steel C3 was used as supplied by the makers, i.e., oil-quenched from 900° C. and tempered at 650° C, with Vickers hardness of 250. It was decided not to try to make its structure more homogeneous by changing the heat-treatment, as this is the condition in which the steel is used commercially. Steel C5 was supplied in the softened condition (Vickers hardness 232) ready for machining, and the steel was nitrided as received from the makers.

The microstructure and hardness of the case were investigated after nitriding under various conditions and the authors conclude that a normally nitrided steel is coated with a "nitride" layer (and γ' of ϵ about 0·03 mm. thick, beneath which is a duplex zone consisting of γ' and ferrite, the proportion of the former decreasing from the surface inward. In pure ammonia the nitride layer forms in a few minutes at 500° C, it is brittle and spalls when severely stressed. The γ'-α aggregate is much less brittle.

The generally accepted explanation that the hardness of nitrided steel is due to "dispersion" hardening caused by sub-microscopic particles of aluminium and chromium nitrides in α-iron accounts for the major part of the hardening, up to about 850 Vickers, but iron nitride hardened by dispersed alloy nitrides is responsible for the intense hardness close to the surface.

The authors conclude that the rate of nitriding is controlled by the rate of diffusion of nitrogen in the steel; the characteristics of the case produced in a given time at a given temperature being largely independent of the composition of the nitriding gas and of the physical condition of the surface of the steel. Once the nitride layer has been formed, the ammonia can be diluted with about ten times its volume of nitrogen or about one-third of its volume of hydrogen without affecting the efficiency of the process and the hardness of the case is not materially affected by rapid cooling or by ageing at room temperature.

It was found that prolonged annealing of a nitrided steel in nitrogen eliminates the visible nitride and reduces the surface hardness to about 850. Similar effects are produced, but more rapidly, by heating in hydrogen. The hardness below the surface is raised and the case depth is increased by annealing.

The process, briefly, consists in heating a special type of steel in a stream of anhydrous ammonia; the ammonia coming into contact with the surface of the steel dissociates into hydrogen and nitrogen, and a proportion of the nitrogen dissolves in the iron, forming a solid solution of nitrogen in α-iron. When this is saturated, it reacts with more nitrogen to form a constituent known as γ', which in turn reacts with nitrogen to form another phase, ϵ. It is possible that this constituent may be converted finally into another phase, differing slightly from ϵ but containing more nitrogen; complete data on this point is lacking.

The major objectives of the investigation were to find whether iron nitride is a normal constituent of nitrided steel, to study the mechanism of nitriding and to find out whether the process could be speeded up by modifying the nitriding conditions, particularly by some preliminary treatment of the surface of the steel.

It was not expected, however, that the physical condition of the surface of the steel would have any appreciable effect on the efficiency of the process, and this was borne out by the experiments. A number of specimens of steel C5 were nitrided for 24 hours in ammonia after preparing them as follows: (*a*) by grinding on Hubert emery paper No. 1, (*b*) by grinding on No. 00 paper, (*c*) by grinding on No. 000 paper, (*d*) by polishing with magnesia on cloth,

and, (e) by polishing with magnesia then etching deeply with 1% nitric acid in alcohol. These treatments had no effect on the process and more drastic surface alteration was tried.

Specimens of steel C3 were heated successively in moist nitrogen (an oxidising agent) and in dry hydrogen (a reducing agent) for seven periods of 40 minutes each, finishing with a 60-minute treatment in hydrogen to ensure complete reduction of the surface of the metal; the temperature used being 500° C. This treatment had no measurable effect on the depth or hardness of the case, but it did appear that the alternating oxidations and reductions had made the nitride layer more brittle than usual.

HOT METAL PRACTICE ON THE NORTH-EAST COAST

No recent account has been published regarding the hot-metal practice of the North-East coast and this paper by Mr. W. Geary describes the methods in present use by reference to the construction and operating of the following plants: Acklam, Britannia, Cleveland North Plant, Cleveland South Plant, and Redcar. Each of these plants is separately described and discussed, with a brief mention of its history and subsequent development, whilst constructional details of mixers and varying designs of steel furnaces from 55 to 250 tons are mentioned and illustrated.

The layout of plant is described, data are supplied for complete charges, with analyses of materials and details of pressure measurements. Recent modifications in furnace construction are given and the author's experience when working the standard hot-metal process in cold-coke-oven-gas furnaces of modern design comprises a fully detailed account. The fuel consumption of these furnaces is given, gas supply and utilisation are discussed, and results are quoted. Casting practice, with indication of the nature of products, is discussed and certain observations concerning factors that experience proves to be of prime importance, are made, these including the supply of materials, effect of furnace design or shop layout, and fuel.

About 80% of the output of the Acklam shop is under 0·13% of carbon, and the greater part of it is rimming steel. During the last nine or ten years the plant has been worked to capacity and it has made over 6,300 tons of ingots a week, nearly all in small sizes, that are rolled in the adjoining mill, the output of which is about 5,200 tons a week of sheet bar, soft billets and small sections.

From its early days the general layout of the Britannia plant remained substantially unaltered, and by improvements in furnace design and in practice, the outputs steadily increased, until between 1914 and 1925 the record furnace output had risen from 837 to 1,105 tons. At this time there were two tilting mixers of 200 and 400 tons capacity, serving two 80-ton and nine 45-ton fixed furnaces. In 1923 the 400-ton mixer was converted to a 250-ton tilting furnace, the average output of which was 1,650 tons a week, until in 1929 a waste-heat boiler and fan were installed, when the output increased to over 2,000 tons. Meanwhile the capacity of the fixed furnaces had been increased by deepening the baths, and in 1930 when the plant closed down owing to the trade depression, the small furnaces were working 55-ton charges and the 80-ton furnaces were tapping up to 120 tons. It was not until the end of 1933 that the plant was restarted, and as steel was urgently required the furnaces were put in commission without alteration. Every opportunity was taken to make improvements; the details furnished by Mr. Geary show that the efforts were successful.

About the year 1885, Messrs. Bolckow, Vaughan and Co., Ltd., built five Batho furnaces at the Cleveland plant, first of 20 and then of 40 tons capacity, which were worked either on the scrap/pig-iron process or with partly blown metal from the Bessemer converters. The line of furnaces was extended between 1913 and 1915 by the construction of seven 60-ton fixed furnaces and two 400-ton mixers. Both the old and the new furnaces worked until 1921, when the Batho furnaces were shut down, eventually being scrapped. The extension, now the North Plant, was in continuous operation from 1913 to 1921, when it was closed down. In 1919-20 the furnaces were each making 700-750 tons per week.

In 1923 the plant worked with three furnaces and one mixer for a period of four months, and during 1927, two, and for a few weeks, three, furnaces worked on cold charging but the plant was once more shut down in March, 1928. It remained idle until the autumn of 1936, when a decision was taken to bring it again into service, and some of the furnaces were pulled down with the object of remodelling them on more modern lines. The remodelling of the furnaces was completed by June, 1937, and by that time the previous record output of the shop, 4,749 tons from six furnaces, had been raised to 6,356 tons obtained from five furnaces.

The erection of the South Plant was started during the war to meet the great demand for steel, but the first furnace was not started up until 1918. By the end of 1921, seven of the eight furnaces were working. The North plant was laid off, and since that time, excluding the 1926 stoppage, the plant has been in continuous operation, but at varying capacity, to the exclusion of the North Plant. Originally, this plant consisted of eight 60-ton basic furnaces and two semi-active 400-ton mixers, all fired from a bank of 30 static water-bottom gas producers. The average make per furnace, with two mixers working, in 1926 was 850 tons per week. In 1927, the fixed furnaces were enlarged from 60 to 75 tons capacity, and in 1928 one of the mixers was converted into a 150-ton tilting furnace, and subsequently in 1930 into a 230-ton tilting furnace. One of the 75-ton furnaces was altered early in 1937 to 140 tons capacity and has only recently been put into operation.

The present maximum output of the plant is 8,790 tons a week. It runs on an average of about 7,500 tons, making rails of all kinds and plain carbon steels over a wide range for the Sheffield trade and other users of first-class semi-finished material. The units at present operating are the 400-ton mixer, a 230-ton tilting furnace, five or six 75-ton fixed furnaces, and a 140-ton fixed furnace.

The erection of the Redcar plant was started and finished during the war, the first cast of steel being tapped in February, 1917. It then consisted of a 400-ton mixer, four 60- to 70-ton fixed furnaces and three 80-ton tilting furnaces, and the output in 1925 was 1,050 to 1,200 tons per week. Very little alteration has been made in the general construction of the plant, but most of the furnaces have been altered. The plant now consists, in addition to the mixer, of four 80-ton fixed furnaces, five 85-ton fixed furnaces and one 85-ton tilting furnace. Its present maximum output is 8,865 tons, but a very valuable feature is that it can and does run at an average make of over 8,000 tons a week with seven furnaces working. The greater part of this steel is in ingots of 7 to 10 tons weight for plates. This plant is the one that works most steel scrap. For many years now the percentage of steel scrap charged into the furnaces has not fallen below 33%. Since the plant is also served with good quality basic iron, it means that the slag volume is low in comparison with that of the other fixed-furnace plants, and there is a correspondingly shorter working time. There was a period during the trade depression when the blast-furnace plant was idle, when the steel plant worked on cold-metal practice, with an average of about 50% scrap.

It is noteworthy that progress in fixed furnace construction has tended towards a standardisation of design, so far as the essential features are concerned, with the exception only of the coke-oven-gas furnaces. Any furnace can be adapted for the hot-metal process, provided only that there are means of slagging off whenever necessary. The tilting furnace has a distinct advantage in this, as it has also in the ability to make soluble slag, and in its gain in yield by not losing a little steel in drainings from each

heat. The type and amount of equipment in a shop will determine the greatest amount of scrap that can be used with advantage, though a shop that operates normally at greatest efficiency with a relatively high percentage of scrap loses some advantage when the scrap price is high. The charging speed in the works under consideration is seldom too fast; only when a combination of a large amount of heavy scrap and a surplus of charging-crane power occurs should there be need for much warming-up. Extra long tap-to-tap times are more often due to delayed charging than to too-rapid charging.

THE THOMAS-GILCHRIST BASIC PROCESS

It is just about fifty-eight years since the commercial possibilities of the basic Bessemer process invented by Sidney Gilchrist Thomas, were demonstrated at the works of Messrs. Bolckow, Vaughan and Co. Ltd., then under the management of the late Mr. E. Windsor Richards. To-day, 90% of the world's output of steel, or about 90,000,000 tons, is produced annually by the basic Bessemer and basic open-hearth processes, so considerable interest is attached to this informative paper by Mr. F. W. Harbord, C.B.E., which reviews the technical and commercial development of this great process. It is particularly interesting that this paper should be presented in Middlesbrough, because the development of the process is due in no small measure to the enterprise of the ironmasters of this town.

Mr. Harbord gives a brief account of the early life and training of S. G. Thomas and the development of the Thomas-Gilchrist process, from the early experiments carried out by himself and Percy Gilchrist in the 6-lb. converter to the present day. He describes the Blaenavon experiments and how the commercial and technical possibilities of the process were demonstrated to the world. The development of the process in Great Britain, on the Continent and in America is traced and mention is made of the conditions under which the basic Bessemer had to operate in Britain with the ores available.

When the basic process was introduced, the acid open-hearth was just beginning to be a serious competitor to the acid Bessemer process and the tendency has been for the open-hearth to supersede, however gradually, the Bessemer in both basic and acid practice. This has been due to the wide distribution of ores containing too much phosphorus for the acid process and too little for the Bessemer, but which produce a pig iron that is very suitable for basic open-hearth practice. This is particularly true of the United States, where widely distributed iron ore deposit produce a pig iron with from 0·2% to 0·5% phosphorus; and to the greater control of the open-hearth process, especially during the finishing stages of which with their latitude for sampling and adjustment.

Thus, there has been a general tendency in recent years for the basic open-hearth process to supplant basic Bessemer in all steel producing countries. The American total of 47,706,000 tons annually contained 43 million tons last year made in the basic open-hearth furnace and in Germany the output of basic open-hearth steel was 8,600,000 tons and 6,800,000 tons made by the basic Bessemer process.

On the other hand, dead soft Bessemer basic steel gives better results for certain purposes, such as for tube strip and certain tinplate work. Largely to meet the requirements of the tube works Messrs. Stewarts and Lloyds Ltd., have recently established a modern basic Bessemer plant at Corby, Northamptonshire, and are now producing about 325,000 tons of basic Bessemer steel per annum, this being from Northamptonshire ore.

In the early days of basic Bessemer practice, to obtain the best results and prevent cold heats, it was found necessary to have not less than 2·0% of phosphorus in the pig iron, but in modern practice with large converters, large metal mixers and every facility for very rapid working, pig iron containing from 1·7% to 1·8% of phosphorus gives quite satisfactory results. This has made the utilisation of Northamptonshire ores easier, as a very small addition of phosphoric material to the blast-furnace burden will enable a pig iron with 1·7% to be produced from Northamptonshire ore, and the extra phosphorus required can be supplied by using low-grade basic slag produced in open-hearth furnaces containing too little phosphoric acid for use as a manure.

The reintroduction of the basic Bessemer process to Great Britain with the utilisation of our home ores is a most important development welcomed by all interested in iron and steel manufacture, both for technical and economic reasons.

The author dealt with the influence of the basic process upon the railway, shipbuilding and engineering industries, and upon the world in general, pointing out that the present total production of basic steel involves the mining of not less than 250 million tons of phosphoric ore each year, which could not otherwise have been used for steelmaking.

No one can say what have been the indirect effects of the development of the Thomas-Gilchrist process, but it is certain that without this invention, or some other process, which enabled the phosphoric ore deposits to be utilised for steel manufacture, the cost of steel would have been so increased that the great developments in railway, ship-building and general engineering during the last sixty years would have been to a very large extent impossible. The cost of transport by sea and land, on which the price of commodities so largely depends, would have been restricted to an extent which it is difficult to realise, and the general conditions of the world would have been very different from what they are to-day.

SOME RECENT EXPERIMENTS IN CONNECTION WITH THE SPRAYING OF STEEL BY THE WIRE-FED METAL-SPRAYING PISTOL

The spraying of the various carbon steels and also, more recently, alloy steels for the purpose of resurfacing and building up worn machine parts has now been adopted as standard practice in many engineering works and in this paper Mr. R. R. Sillifant describes some experiments conducted with a view to improving the quality of deposits made in this kind of work, using the wire-fed type of pistol. The author explains some experiments carried out in connection with the fuel gases—compressed coal-gas, hydrogen and dissolved acetylene—with respect to the deoxidising effects of reducing flames. When using the oxy-acetylene flame it was found that a secondary flame uses oxygen from the atmosphere and it was decided to assess the volume of oxygen in the blast air and to ascertain exactly how much of this was absorbed by the secondary acetylene flame.

It was found that an appreciable amount of oxygen remained in the blast air, sufficient to be considered objectionable at the tip of the wire, and experiments were carried out with an inert gas instead of the air-blast. The use of nitrogen as an impelling medium is considered, and the result of the experiments indicate that beneficial results may be expected with sprayed-steel deposits by using dissolved hydrogen as the fuel gas in conjunction with an inert gas or deoxidised air as the impelling medium, coupled with suitable heat-treatment after spraying.

Where steel deposits of high quality are demanded, such as on machine parts subject to heavy varying loads, these methods may prove of assistance when applied by experienced users of the metal-spraying process, although the cost is high, since nitrogen is not used in sufficient quantities at the present time to make its price economic.

Further, the application of these principles to deposits of metals other than steel may, with time, find favour in the metal-spraying industry, because improved mechanical and physical properties can be expected from treated deposits which will widen the scope of the process still further.

VARIATION IN THICKNESS OF THE TIN COATING OF TINPLATE, AND ITS EFFECT ON POROSITY

Porosity in the tin coating of tinplate has, in past years, been ascribed to many causes, and various suggestions have been made from time to time as to how it might be decreased or eliminated. In spite of the guidance of these suggestions, it has not yet been found possible to effect any substantial reduction in the porosity of such tin coatings as are generally used in the canning industry. This paper, by Mr. W. E. Hoare, is an attempt to throw light on the relation between the tin coating thickness and the porosity, and to examine any implications of the relation.

From a series of experiments which covered such factors as tin yield, pressure and type of absorbent material, the author drew some fairly definite conclusions, these being: (*a*) That the type of absorbent used had little effect on the increase of porosity (except for flue dust which causes considerable scratching, and unsieved sawdust); (*b*) The increase of porosity with cleaning depends upon the tin yield; when this is above 4 lb. per basis box the numerical increase of porosity is small, and above 8 lb. per basis box no increases were obtained; (*c*) A marked effect of the cleaning operation is the enlargement of existing pore sites, particularly is this so in the case of thin coatings; (*d*) The increase of porosity varies enormously with the pressure between the specimen and the polishing medium, an effect which needs further investigation; and (*e*) It appears that cleaning porosity is due to isolated particles in the absorbent or on the rolls, rather than to any intrinsic general property of the absorbent itself, the scratches which produce porosity are usually quite distinct from the general abrasion and lead to the suspicion that they may be due to foreign particles.

The author suggested that, in general, attention should be paid to the cleanliness of operation and the intrusion of grit obviated as far as possible, the minimum pressure which achieves the desired result should be used, and the use of hard and sharp abrasives, particularly such as flue-dust, should be avoided.

It was found that the number of pores per 100 sq. cm. falls from 8,000 to 300 as the coating thickness was increased from 1 lb. to 3 lb. per basis box, and falls more slowly from 300 to two as the coating thickness was further increased to 15 lb. per basis box. Consideration of the shape of the tin-yield/porosity curve showed that local variation of the coating thickness tends to produce over-sheet increase on porosity.

The author commented upon "bridging over" of potential sites of normal pores and its implications and confirmed the theroetical findings of Chalmers with respect to the minimum pore size possible for any particular coating thickness.

Comments on the mode of formation of microscopic irregularities were made, the most important conclusion in this regard being that a periodic variation of coating thickness occurs across the direction of tinning, or the lines of convexity in the direction of tinning, the periodicity coinciding with that of the grease lines. The existence of these periodic variations, known as "tin ridges" has been confirmed by several methods. These ridges receive tin from other parts of the surface and troughs are created in which the tin yield falls to approximately 60% of the mean value.

SOME ALLOYS FOR USE AT HIGH TEMPERATURES

The work described in this paper by Dr. C. H. M. Jenkins, Mr. E. H. Bucknall, Dr. C. R. Austin and Mr. G. A. Mellor is part of work carried out at the National Physical Laboratory for the Committee on the Behaviour of Materials at High Temperatures appointed by the Metallurgy Research Board. The paper deals with investigations on the constitution of the alloys of nickel, chromium, and iron, and include a review of the literature up to September, 1936. For convenience the authors have divided the paper into four sections relating to (*a*) chromium-iron alloys, (*b*) nickel-iron alloys, (*c*) nickel-chromium alloys and (*d*) nickel-chromium-iron alloys. No experimental work is described under section (*a*), but details of new experimental work are given in sections (*b*), (*c*) and (*d*). This comprises a determination of the solidus of the nickel-iron system, reinvestigations of the liquidus and solidus temperatures and solid constitution, *at temperatures above* 800° C., of the nickel-chromium alloys and of the nickel-chromium-iron alloys containing up to 50% of chromium. The phase diagram of the ternary alloys is illustrated by horizontal sections.

The determination of the solidus of nickel-iron alloys was obtained by quenching experiments. Nicu alloys were made up as small melts *in vacuo* in the high-frequency induction furnace from specially selected high quality nickel shot and electrolytic iron which had been purified by treatment in hydrogen when molten. These melts were allowed to solidify in the crucibles *in vacuo*. The ingots were given prolonged annealing treatments to remove coring, after which pieces were maintained for 15 minutes at temperatures near the liquidus and quenched in cold water. The microstructure was then examined and the solidus curve from the results is shown to pass through a minimum below that of the liquids. This determination of the solidus is used in the construction of the ternary diagram.

As a result of experiments with nickel-chromium alloys, conclusion from earlier experiments with cold-worked alloys made from a commercial grade of chromium is confirmed, namely, that the solid solubility of chromium in nickel at 800° C. lies below 40 but above 30%. Alloys containing more than 65% of nickel were found to be homogeneous after all the heat-treatments at temperatures above 800° C. to which they had been subjected. The alloy *N*60*C*40 is homogeneous at a temperature of 950° C. and above, but duplex at 800° C., whilst *N*55*C*45 is homogeneous at 1,200° C., but shows a small separation of the second constituent at 1,100° C. The alloy *N*53*C*47 is homogeneous at 1,335° C., but duplex at 1,320° C., whilst *N*51*C*49 and alloys of somewhat higher chromium content are duplex at all temperatures from 800° to 1,335° C.

The course of the boundary of the nickel-rich γ phase is regarded as being well established, but the boundary of the chromium-rich α phase is not so closely determined by the work in its present form. The attainment of equilibrium in these alloys is extremely slow; for example, one of the ingots containing 90% of chromium exhibited a cored structure after annealing for three days at 1,300°C Another feature of the chromium-rich alloys which rendered difficult the interpretation of the microstructures of chromium-rich alloys was the appearance of markings in certain of the annealed samples, or a second constituent in the form of needles, which lie along certain of the crystalographic planes of the α phase.

The liquidus and solidus curves as a result of the experimental survey are known up to about 80 and 90% chromium respectively. The solid constitution at high temperatures has also been explored and the existence of only two phases in the system confirmed. The boundary of the chromium-rich α phase has not yet been determined precisely, but the indications tend to confirm the form suggested by Nishigori and Hamasumi.

In this work on the nickel-chromium-iron alloys the materials employed have been somewhat purer, and microscopical study of the alloys after annealing has defined more closely the constitution of the alloys between the liquidus temperature and 800° C. than in previous investigations. Five series of alloys were studied corresponding to chromium contents of 10, 20, 30, 40 and 50%, with nickel and iron contents in stages of approximately 10%.

The values of the liquidus arrests on heating and cooling are averaged and the liquidus surface is indicated by means of isothermal contours at 10° C. intervals which have been smoothed to approximately ± 3° C. The liquidus surface put forward differs from that of Wever and Jellinghaus mainly in that the valley line connecting the eutectic point of the nickel-chromium system with the end of the peritectic horizontal of the system iron-nickel is now shown not to rise smoothly from the eutectic temperature, 1342° C., to the peritectic temperature, 1,499° C., but at first to fall and only later to rise. The point of minimum temperature represents an alloy which solidfies at constant temperature, just as does the binary eutectic, and may be referred to as a depressed binary eutectic point. It is suggested that this point lies near the composition 49% chromium, 8% iron, 43% nickel, with a melting point below 1,300° C., but the main evidence for the existence of this is derived from the solidus determinations.

The results of quenching experiments to determine the solidus temperatures are given. The solidus surface is represented by isothermal contours at 10° C. intervals. This surface consists of three parts, namely, (1) the interface between the γ + liquid and γ fields, corresponding to nickel-rich alloys, (2) the interface between the α + liquid and α fields, corresponding to alloys of low nickel content, and (3) the interface between an $\alpha + \gamma +$ liquid field and the $\alpha + \gamma$ field, underlying the valley line in the liquid surface. This third surface is a "ruled surface." i.e., horizontal sections are straight lines, but at the depressed eutectic point it narrows to a point, which lies at a temperature below 1,312° C., the solidus temperature for the alloy *N40C50F10*, and probably below 1,300° C. Between the boundaries of this part of the solidus surface and the liquidus valley line lie the interfaces of the $\alpha + \gamma +$ liquid field with the α + liquid and the γ + liquid fields which are again ruled surfaces.

Diagrams show that in the alloys containing up to 50% of iron, the solubility of chromium in the γ phase decreases with fall of temperature; except in the alloys containing least iron, the decrease is mainly confined to the temperature range between the solidus and 1,200° C. The solubility of nickel in the α phase decreases with fall of temperature in alloys of all iron contents up to 90%.

EXPERIMENTS ON THE NITROGEN-HARDENING OF HIGH-CHROMIUM AND AUSTENITIC STEELS

Copper-plating by electrodeposition, after a preliminary pickling of the steels in sulphuric acid, is very widely used for nitriding austenitic chromium-nickel-tungsten heat-resisting steels. In view of the commercial interest of certain nitrided austenitic steels, Mr. B. Jones has carried out further experiments dealing with the copper-plating method and the more recently developed phosphate method, for the treatment of various steels before nitriding, the results of which are described in this paper.

The nitrogen-hardening properties of high-chromium and austenitic steels have been investigated after these treatments and regular hardening has been obtained. The greatest hardening was produced by nitriding within the range 500-550° C.; a temperature of 600-610° C. is suitable for only the more highly-alloyed materials, such as the heat-resisting steels. Nitriding at a temperature greater than 600-610° C. results in decreased hardness values for all steels, and the increase in case depth is negligible for austenitic steels. X-ray crystal analysis and microscopical examination were carried out on some of the nitrided steels. X-ray diffraction spectra were obtained from the surface and at various depths within the nitrided case to determine its chemical constitution after nitriding at 550° C.

The surfaces of the ingot iron, 8% nickel steel, and 13% chromium steel show the presence of the ϵ-phase of the iron-nitrogen system, indicating a nitrogen content of approximately 8-11%. This phase is not revealed in the austenitic steels. The surface layer of the 18/8 chromium-nickel steel consists of the γ' Fe_4N phase, together with chromium nitride, CrN. No evidence was obtained for the formation of a nitride of nickel in any of the steels examined, but, in the austenitic steels, nickel is probably dissolved in the nitrides formed, by a replacement of the metal atoms. The 14/14/2 chromium-nickel-tungsten steel gives lines at the surface which indicate the presence of the γ' nitride phase, corresponding to the composition $(FeCrNi)_4N$. While the spectrum lines obtained from the nitrided ingot iron are well defined and show no distortion, those found in the nitrided high-chromium and austenitic steels are highly diffused.

In the steels examined, tests indicate that both the alloy nitride and the crystal lattice of the steel itself are highly distorted, the distortion being so marked as to prevent the formation of a normal spectrum. A change of constitution has occurred in the nitrided 18/8 chromium-nickel steel, as shown by the presence of α-iron lines in the nitrided zone, the atomic lattice being, however, very distorted. The presence of α-iron was not detected in the more stable austenitic alloy, the 14/14/2 chromium-nickel-tungsten steel, but the γ-iron lattice was very distorted, as shown by the very diffused spectrum lines in the zone of greatest hardness.

Summarising the results of the experiments the author states that while good results have been obtained by nitriding high-chromium and austenitic steels after treatment by the methods referred to, the high-chromium steels are rapidly attacked by the phosphate reagent and the time of treatment must be carefully regulated. Nitriding certain high-chromium and austenitic steels at a temperature greater than 550° C. results in a marked decrease in hardening. When the nickel content of austenitic steels is raised, as in the heat-resisting steels, a nitriding temperature of 600° C. is also satisfactory. Higher temperatures are deleterious for all steels.

The nitrided surface consists of the nitrides of iron and of the alloying elements, the composition of which has been ascertained. The maximum hardening effect is found below, and is associated with extraordinarily diffused spectra of the alloy, indicating great distortion of the atomic lattice. Nickel does not form a separate nitride, but it is probable that the element dissolves in the lattice of the nitrides of iron and chromium by a replacement of atoms. Nickel, therefore, does not cause nitride-hardening which is due, in the steels examined, to the presence of finely-dispersed nitrides containing chromium of an almost amorphous size.

A NEW METHOD FOR JUDGING THE BEHAVIOUR OF IRON ORES DURING REDUCTION

In this paper by Dr. N. J. Klärding a brief reference is made to the reactions occurring during the reduction of iron-oxide by carbon monoxide and a method and apparatus is described for investigating them. The apparatus used consists of electrically heated reaction tubes, each being connected to a mercury manometer. Each evacuated reaction tube is filled with carbon monoxide from a gauged vessel to which a manometer is connected. The resulting difference of pressure before and after filling the tube provides an easy means of calculating the quantity of carbon monoxide added.

Reduction curves for pure Fe_2O_3 obtained by Schenck and Dingmann are presented, and the influence of the temperature on the conversion of carbon monoxide into carbon dioxide is indicated. The phases formed in the iron-oxygen system as a result of these reactions are then innumerated. Finally, isothermal reduction curves for ores from Rio Tinto, Newfoundland and Lucainena (Spain) are presented and discussed.

Blast-Furnace Field Tests

An investigation of a blast-furnace smelting principally Lincolnshire ores at the Frodingham Works of the Appleby-Frodingham Steel Co., Ltd.

THE blast-furnace placed at the disposal of the Blast-Furnace Reactions Research Sub-Committee of the Iron and Steel Industrial Research Council, by the Appleby-Frodingham Steel Co. Ltd., for investigation, smelts principally Lincolnshire ores with South Yorkshire coke. The actual experimental work involved by the investigation was carried out by Dr. Stacey Ward and the technical and works staff of the Appleby-Frodingham Steel Co. Ltd., under the general supervision of Professor Bone. The Sub-Committee appointed a special panel of its members to assist, which included Professor W. A. Bone, F.R.S. (Chairman); Messrs. C. A. J. Behrendt, F. Clements, A. Crooke, E. C. Evans, R. A. Hacking, Drs. D. M. Newitt, H. L. Saunders, S. G. Ward, Messrs. H. R. B. Walshaw, J. M. Ridgion (Secretary).

The report describes the experimental procedure and the apparatus employed, as well as details of the principal results obtained, and it discusses their implications and significance. It should, however, be understood that, while the results obtained are valid for the special conditions of Lincolnshire ore-smelting, different results and inferences may be forthcoming when the investigation is extended to other typical ore-smelting conditions. For it has already become clear that in all probability what may be termed the characteristic feature of the temperature distribution and variations in the physico-chemical conditions throughout a particular blast-furnace will be found to vary with differences in the character of the ores smelted, possibly also, of the fuel employed, as well as with differences in established practice between the principal smelting localities—hence the desirability of extending the inquiry. And in this connection it should be mentioned that already a similar inquiry into the smelting of calcined Cleveland ore with Durham coke is now being undertaken on a furnace at the Skinningrove Iron Co.'s works in co-operation with the President of the Iron and Steel Institute and his works technical staff. In due course it is hoped to investigate also other typical British smelting conditions with a view to determining the characteristic physico-chemical feature of each, of comparing one with another, and ultimately of co-ordinating the results as a whole with those of the fundamental laboratory investigation which is being simultaneously carried out by Professor Bone and his colleagues in the laboratories of the Bone Research Association at the Imperial College, London. In this way it is hoped to extend and complete, as regards British ore-smelting, the classical work begun by Lowthian Bell, at the Clarence Works, Middlesbrough, 70 years ago, and so to provide a new scientific basis for British blast-furnace practice.

In order to arrive at a true general perception of the conditions prevailing throughout the stack as a whole, it was necessary to deduce proper statistical averages for the numerous temperature measurements and gas compositions at each sampling point. In view, however, of the considerable variations in such measurements found at each sampling point, and of the importance of eliminating possible errors in the statistical methods employed for determining such averages, the whole of the data were submitted for independent examination. It should, however, be repeated that such "average" results, while generally valid for the particular furnace and smelting conditions concerned, cannot be claimed to be necessarily applicable to other furnaces operating upon other ores and fuel, under widely different conditions as to rates of driving and distribution of the burden within the stack. For, as already stated, other furnaces and smelting conditions will have to be similarly investigated before any more general conclusions can be drawn.

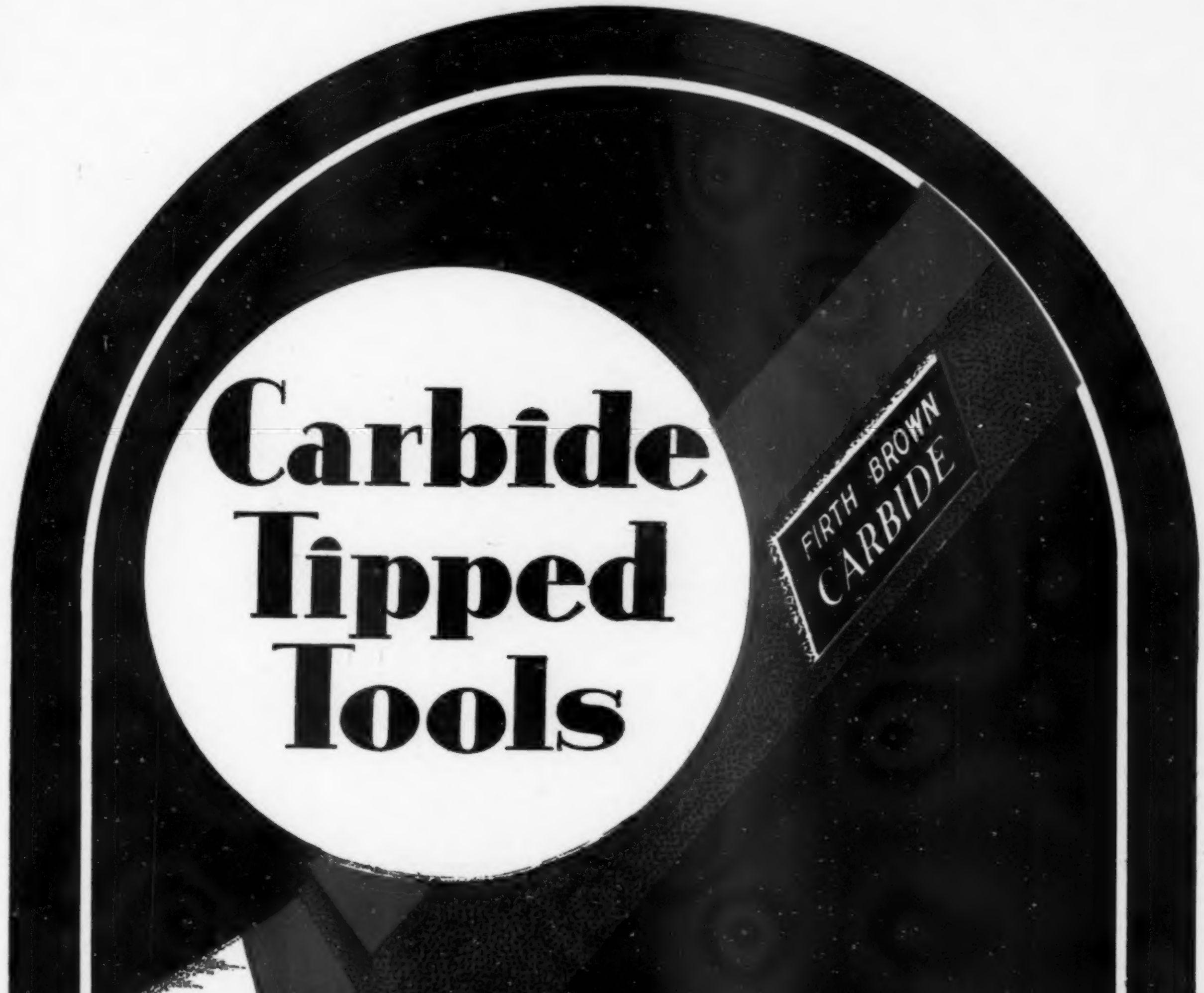
Perhaps the most striking and revealing feature of the results is the fact that the temperature and physico-chemical conditions were found to be far from uniform across any one of the selected horizontal planes in the furnace, thus proving that, in this particular case at all events, any conception of "uniformity" in the conditions across a given horizontal plane must be ruled out as fallacious. In fact, apart from a slight fall in temperature just at the inwall, doubtless due to the cooling effect of the stack-wall and its coolers, the temperatures observed across any given plane were usually higher at the centre and near the inwall than at intermediate points, and reached a minimum at points usually nearer to the inwall than to the centre.

The results of the investigation as a whole may be said to have stressed the importance of the proper sizing and distribution of the solid burden within the furnace. The material comprising the burden of this particular furnace varied in size from lumps of ore weighing 60 lb. (and sometimes more) down to dust, and were charged into the furnace from a bell 13 ft. in diameter with an angle of 45°. The fines and smaller pieces fell from it almost vertically, while the large pieces rolled down towards the centre and the wall, so that the stock-line assumed a very irregular contour. Doubtless a more even size-distribution of the burden, could it have been ensured, would have been reflected in better and more uniform working conditions throughout the furnace.

A further cause of irregularity in the working of this furnace may perhaps be variations in the compositions of the ores used (apart from a small amount of foreign ore), not only from stratum to stratum in the beds, but also along (and away from) the working faces in the mines. The heterogeneity comprised not only the chemical composition, but also the size and hardness of the component strata; consequently a change in the chemical composition of the rocks composing the ores would most likely be accompanied by an alteration in the proportions of the various sizes present. Thus, although a chemical analysis used in burdening the furnace may be used also to determine fairly accurately the ultimate slag composition, it gives no information concerning the changes which will occur in the conditions within the stack when a change-over or alteration is made, because it does not take into account the effect of the physical properties, size and distribution of the component elements throughout the different sizes.

Another factor connected with size-distribution is the influence which it might be expected to exert upon carbon deposition in the upper region of the furnace. In the case of the particular furnace under investigation, it is clear that the most favourable region for carbon deposition would be directly beneath the rim of the bell where the temperature was lowest, the gas velocity slowest, and the ore size smallest. And, as carbon impregnation and deposition proceeded, "voids" would close up, with a further slowing of the gas stream and increase in the time of contact between the gas and ore in the region concerned, the initial irregularity becoming accentuated thereby. Here again, a better sizing of the ore within closer limits might have resulted in a better distribution of the deposited impregnated carbon and consequently in more uniform working.

A very complete description is given of the blast-furnace, together with all the experimental data and numerous drawings, which make this report a very valuable contribution to the knowledge on blast-furnace smelting.

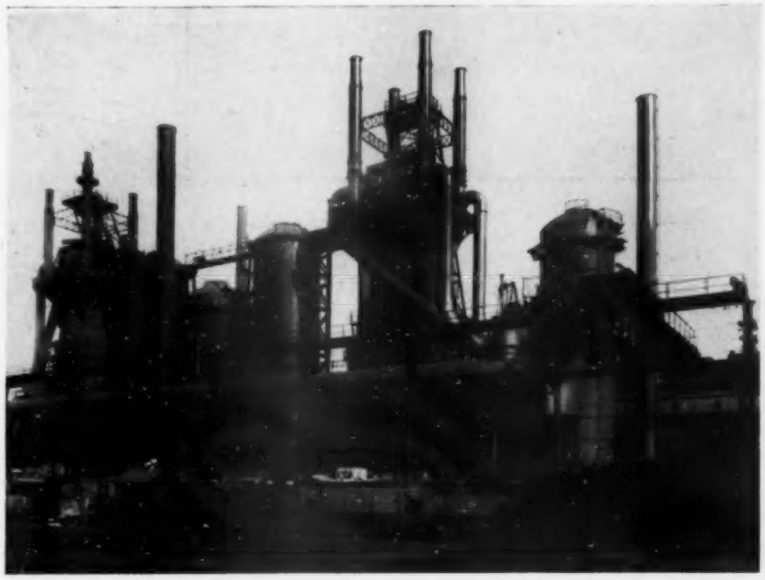

Carbide
Tipped
Tools
FIRTH BROWN
CARBIDE
THESE Tools are the result of many years of research not only of the methods of manufacture of carbide but also of the production and geometry of lathe tools. In every respect they match up to the excellence of all other Firth-Brown Engineers' Tool Department products.
THOS FIRTH & JOHN BROWN LTD
SHEFFIELD

Works in the Cleveland District

Unusual interest was attached to the works visits arranged in connection with the Middlesbrough Meeting of the Iron and Steel Institute, some of which are briefly described in this review.

THE moorland district of the North Riding of Yorkshire, known as the Cleveland district, is chiefly important for its remarkably rich deposits of ironstone, which supply the iron-working industry of Middlesbrough and other centres in this area. Great progress in the working of this mineral has been made since about the middle of the nineteenth century, when the discovery of the basic Bessemer process had a special significance; since that time many small villages have become busy towns. Some of the works in these towns were opened to members attending the Iron and Steel Institute Autumn Meeting at Middlesbrough, and were found to be both interesting and informative.

The various visits covered nearly every aspect of iron and steel production and fabrication, including coke-oven installations, blast-furnaces, cogging and rolling mills, sheet, plate, and wire mills, and heat-treatment plant. Another most interesting development, though not so closely associated with iron and steel, is that of the Imperial Chemical Industries Ltd., whose vast hydrogenation plant was visited by a limited number of members.



No. 1 and 3 Bessemer blast-furnaces at the Cleveland Works of Dorman, Long and Co., Ltd.

Dorman, Long & Co. Ltd.

THE history of Messrs. Dorman, Long and Co., Ltd., whose Acklam, Britannia, Cleveland and Redcar works were visited by members of the Iron and Steel Institute on September 15, 16 and 17, dates from 1875, when the late Sir Arthur J. Dorman, Bt., entered into partnership with Mr. A. de Lande Long and acquired the West Marsh Works of the West Marsh Iron Co. The original equipment of the works included 20 puddling furnaces, shingling hammer, puddled bar rolling mill and a 14-inch finishing mill. The new company added a 10-inch rolling mill and produced bars and angles.

As business grew, they leased the adjacent Britannia Works and acquired these works in 1880. The change-over from iron to steel production was made in 1886. The puddling furnaces were replaced by Siemens-Martin open-hearth furnaces, adopting the basic process in 1901.

The company became a limited company in 1889, and the annual steel output then reached 100,000 tons, a figure which has since risen to 1,750,000 tons at the present time. Steel was rapidly replacing iron for bridge work in 1890. Eight years later steadily expanding business caused the company to purchase the Ayrton sheet mills and the Cleveland Wire Mills. The ordinary share capital of the North Eastern Steel Co. Ltd. was acquired in 1903, ironstone mines and six blast furnaces at Redcar were added in 1915, and the following year the Redcar steel and plate mills were laid down. 1917 saw the Newport iron-works brought under control of the firm, and in 1929 the important firm of Bolckow, Vaughan and Co. Ltd. was amalgamated, including their large iron and steel works at South Bank, many collieries and limestone quarries in the county of Durham, together with several important ironstone mines in Cleveland, North Yorkshire and Durham.

The process of absorption of iron and steel works, collieries and quarries over a period of roughly 37 years, has resulted in Dorman, Long and Co. Ltd., being one of the largest coal, iron and steel undertakings under one management in Great Britain — with blast furnaces producing 1½ million tons of pig iron annually and a similar total production of semi-finished and finished steel from the rolling mills.

On the Wednesday, visitors saw the coke-ovens and by-product plant, blast-furnaces, steel works and rolling mills and the excellent railway transport facilities of the Acklam works. The batteries of 120 Simon-Carves regenerative type coke ovens have an output of 400 tons of coke each week, with an available surplus of 4 million cubic feet of gas per day, part of which is sent to the Middlesbrough Corporation in conjunction with gas from the Company's Newport coke ovens, the latter being their main source of supply. The disintegrators are placed immediately above the 1,000-ton crushed-coal storage bunker, the propelling action of the discharge from the disintegrators having a distributing effect which renders the charge self-trimming.

Of the four blast-furnaces, three can be operated simultaneously. The three furnaces produce at the rate of approximately 332,000 tons a year; blast-furnace gas is taken off from each furnace by four downcomers led in pairs into a dust catcher of 12 ft. diameter at each side of the furnace, the heavier dust being deposited. Collected dust is removed daily from the dirty-gas main extending the full length of the furnaces. The crude gas then passes through four primary washing towers of 56 ft. high each and the rough-cleaned gas then passes through four Theisen washers, each of which has a capacity of 1¼ million cubic feet per hour. When they leave these washers the gases have a dust content not exceeding 0·01 gramme per cubic metre.

The steel-melting plant consists of a 400-ton mixer, fired with a mixture of coke-oven and producer gas. It can however, be fired with blast furnace gas. Molten metal is brought in 30-ton transfer ladles to this mixer.

Redcar steel furnaces of Dorman, Long and Co., Ltd.

The three basic open-hearth tilting furnaces have each a capacity of 250 tons and the steel ingot output capacity is over 2,000 tons per week each. In the casting bay there are two 100-ton casting cranes with 15-ton auxiliary hoists; the ingots are cast on carriages, each carriage holding six moulds for ingots up to 3½ tons weight. A 5-ton stripper crane is in an adjacent shed. The six soaking pits are fired by blast-furnace gas, the gas and air being regulated by Hagan controllers and the pits are served by two Wellman ingot-charging cranes.

Cold ingots are delivered from the stocking ground by a bogie conveyer and hot ingots from the stripping shed travel to the soaking pits on carriages drawn by a locomotive. Ingots are transported from the soaking pits to the cogging mill train by an ingot chair, and this is hauled by an electrically-driven winch, the chair being automatically tipped at the ingoing side of the mill.

No. 1 mill is two-stand two-high and the roughing stand of the No. 2 mill is close to the cogging mill and in line with it. The two mills are adaptable for sheet bars, billets, slabs, rails and sections and have an average output of 300 tons per shift.

There are two generating stations, No. 1, containing four 12-cylinder tandem vertical National gas engines operating on blast-furnace gas, each 1,500 h.p. engine being direct-coupled to an alternator. No. 2 station contains two mixed pressure turbo-alternator sets. About 80% of the output is obtained from the exhaust steam from the rolling mill engines, when this is not available live steam is supplied from the mill boilers. Visitors noticed that the electricity system is coupled to a similar system at the Britannia Works, so that interchange of power is possible between the two works.

The Britannia Works which were visited on the same day, occupy an area of about 60 acres on the River Tees and with direct connection with the L.N.E. Rly.

The steelworks are supplied with molten metal brought in 30-ton ladles from the Acklam furnaces. The present furnaces are a 250-ton tilting type (converted from a 400-ton mixer), two 100-ton furnaces and two 50-tonners and a 500-ton mixer. The stripped ingots are taken in batches of 12 on ingot bogies to the soaking pits, there being four dome pits and two nests of Stein and Atkinson soaking pits served by a 7-ton overhead crane.

A hydraulically operated chair feeds the ingots to the cogging mill and the blooms travel along a roller track to one of the finishing mills on either side of the engine house. No. 1 mill has three stands of two-high rolls for first roughing second roughing and finishing; No. 2 mill has two stands of two-high rolls for roughing and finishing and No. 3 and No. 4 mills are housed in a separate building, No. 4 being tandem with the cogging mill.

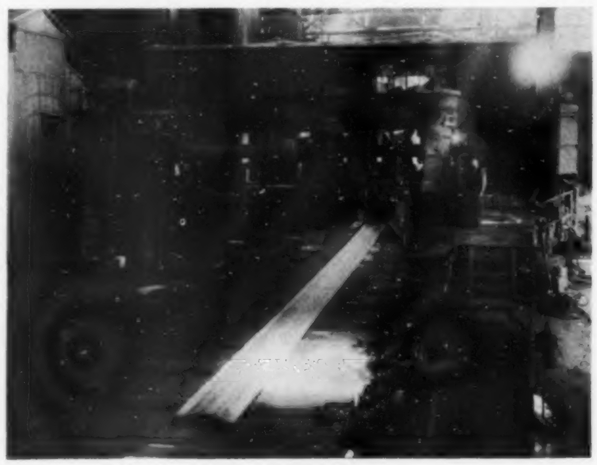
Steel sheet piling and the necessary sections produced in the mills are passed to a portion of the yard laid off for assembly ready for driving. The power house contains a Metro-Vickers 2,000 kW. mixed-pressure turbo-generator set; two English Electric mixed-pressure turbo-generators of 1,600 kW. each; and a rotary convertor. The power station is linked up with the Acklam Works plant.

The Cleveland works were originally owned by Bolckow, Vaughan and Co., Ltd. and were visited on the Wednesday. It was at these works that the early experiments and development of the Thomas basic process enabled the pioneers to utilise the native Cleveland phosphoric ironstone for steel making.

These works comprise coke-ovens, blast-furnaces, steelworks and rolling mills. The coke oven plant is the largest single installation to be built in the kingdom; the 13 blast-furnaces are divided into four groups; five Cleveland furnaces, two Bessemer furnaces, two Grangetown furnaces and four South Bank furnaces. 12 of these furnaces are in blast and produce basic, hæmatite and foundry pig iron and ferro manganese, with a current total output of 12,650 tons a week.

The North melting plant comprises two 400-ton mixers and six open-hearth furnaces, each of 100 tons capacity. In the South melting plant are six open-hearth 75-ton furnaces, one 250-ton and one 150-ton furnace and a 400-ton mixer, the furnaces being fired by a mixture of coke-oven and producer gas.

In the cogging mill 22-inch ingots are cogged down to 6-inch blooms for the rail mill and also for the new 14-inch section mill. There are two-high roughing and finishing stands with 34-inch rolls, and in the mill for sections and bars there is a 40-inch cogging mill and a 20-inch section mill, also a new light section mill has recently been installed (to the design of Schloemann A.-G.).



Universal plate-mill at the Redcar Works of Dorman, Long and Co., Ltd.

At the Redcar Iron and Steel Works the visitors saw the four blast-furnaces, two of which have been rebuilt and are in operation, the calcining stoves for the Cleveland ironstone adjoining the furnaces and the Halberg-Beth gas cleaning plant with a capacity of 3 million cubic feet per hour.

The coke-oven plant comprises a battery of 65 Hussener type and six regenerative type coke-ovens and is complete with by-product and auxiliary plant.

The steel melting plant consists of nine 80–85-ton Siemens-Martin open-hearth furnaces; one 400-ton mixer and an additional steel furnace is being built. Molten basic iron is brought by locomotive from the furnaces in 34-ton ladles and the present output of the steel furnaces is 8,000 tons per week.

The rolling mill equipment was specially interesting, as the cogging mill is one of the largest of its type in the country; the cogged and sheared slabs are charged into the producer gas-fired heating furnaces and delivered to the plate mill by an overhead charger. There is a 9 ft.

9 in. plate mill and a universal plate mill, the latter is equipped with vertical rolls on each side of the horizontal rolls and rolls plates 45 inches wide down to 12 inches in width with perfectly square edges.

These four works were again visited the following day and members also inspected the Ayrton Sheet Mills and the Cleveland Wire Mills. At the former they saw sheet bars delivered from the Acklam Works, cut to length and charged into one of the four bar furnaces. There are seven pairs of hot and three pairs of cold rolls, arranged in line, and seven double-pack furnaces burning clean blast furnace gas from the Acklam Works. The bars are brushed with water before passing through the rolls. The annealing furnace is of the tunnel type, built by Priest Furnaces, Ltd.; the average weight of the packs charged is 12 tons, these taking from 24 to 26 hours to pass through the furnace which is also fired with blast furnace gas. The galvanising department comprises a pickling tank, three galvanising machines and two corrugating machines. The output of the Cleveland Wire Works covers the complete range of high-carbon and mild steel rods and wires, galvanised steel hawser wire, rigging and seizing wire, drawn galvanised wire, electric welding wire, copper coated wire, galvanised wire by the "Crapo" process, stranded wire and barbed wire.

The mill consists of a train of eight pairs of roughing and a train of nine pairs of finishing rolls. The two trains are in parallel, so that the first pair of roughing rolls and the finishing pass are side by side. The rods are passed from the mill to the hydrochloric acid cleaning tanks, then swilled with water, allowed to tarnish, limed to prevent rusting and dried before passing to the drawing shop. Here there are some 100 drawing blocks, the dies of hard steel alloy, and a special high quality drawing-soap is used as a lubricant. One foot of the original billet becomes a mile of 22 gauge wire.

Low-carbon wire is annealed in a 750° C. molten lead bath, in which wire ¼ inch diameter can be annealed in 30 seconds. High tensile wire is passed through a special type of muffle furnace, the wires being drawn in separate strands through tubes around which the furnace gases flow.

Wire fabrication is carried out in a continuation of the drawing shop; batteries of machines manufacturing barbed wire and stranding wire, wire staples; also rod straightening and cutting to length.

Finally, on the Friday, the Cleveland by-product plant was seen, where by-products of the Company's numerous coke ovens are distilled.

This is at Port Clarence on the Durham Bank of the River Tees and is really a self-contained works of the Company, although outside purchases are made for distillation purposes. 6,000,000 gallons of crude benzol and 110,000 tons of tar are dealt with each year. There are 11 stills for benzol distillation, of capacities up to 10,000 gallons each and the tar distillation plant comprises 11 pot stills of 17 tons capacity each and a Wilton continuous tar plant with a capacity of 500 tons of tar per week is under construction.

The principal products of this works are: motor spirit to "National" specifications; crude pyridine; pure benzol; pure and commercial grades of toluol; xylol; solvent and heavy naphthas; all grades of creosote oil; anthracene oil; benzol absorbing oil; cresylic acid (55% meta content carbolic acid); naphthalene; pitch; tar for road works, and a special less toxic tar; "Clarenite" black bituminous paints and tar oil wash for fruit trees.

Head, Wrightson and Co. Ltd.

THE works of Head, Wrightson and Company Limited, at Thornaby-on-Tees, which members of the Institute visited, are among the largest engineering works in the country mainly devoted to the manufacture of specialised equipment for blast-furnace and steelworks plant, and the sheet and tin-plate industry.

Founded almost a hundred years ago, the four works of the organisation now cover 64 acres. The principal unit, namely, Teesdale Iron Works, which the members inspected, is a good example of an almost fully integrated general engineering works. It contains iron foundries, steel foundries, pattern shops, heavy machine shops, forgings and stampings department, and a large structural department suitable for heavy constructional work, with an additional section entirely devoted to welding.

General View of the works of Head, Wrightson and Co., Ltd.

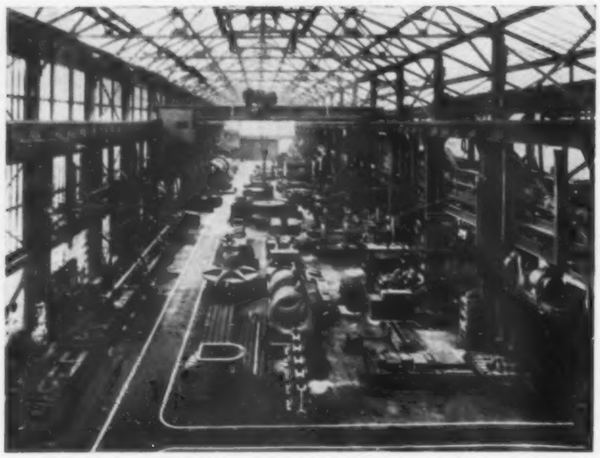
Almost every blast-furnace on the North-East Coast was at one time or another constructed by the firm, and there is hardly a steelworks in the country which does not possess its equipment. The iron foundries produce a variety of jobbing and mass production castings, including hematite ingot moulds for steelworks. Members had the opportunity of seeing railway chairs in the course of manufacture, various jobbing castings (hæmatite blast-furnace bells, etc.) and the ingot mould foundry.

The Electric Steel Foundry at Teesdale with a capacity of 8,000 tons a year produces carbon, manganese and special alloy steels. Here were seen a large variety of high-class steel castings in various stages of production, and also saw some of the latest heat-resisting steels and their application to high temperature work in furnaces, gas producers and other steelworks' equipment. The Company market three grades of heat-resisting steel under the names of "Shadrach," "Meshach" and "Abednego." A feature of the electric steel foundry is the newly installed sand blast plant.

During the visit of the Institute, the heavy machine shops were employed on castings for new steelworks equipment manufactured by the Company in agreement with The Aetna Standard Engineering Company, of Youngstown, Ohio. These machines are designed specifically for the sheet and tin-plate industries and the non-ferrous rolling mills. Another point of interest was the units of a continuous pickling and sorting machine of very modern design.

In the drop forgings and stampings department parts for automobiles were seen manufactured from special alloy steels followed by carefully controlled heat-treatment and inspection. Members watched the production of dies on a Keller die sinking machine, which is fully automatic. Proceeding to the bridge yard by the heavy plate shop a large variety of heavy plate work was inspected, including steelworks ladles, tube mill shells, transfer cars and the earlier stages of other structures including four swing bridges for Egypt.

In the wagon department the production of 20-ton hopper wagons for the London and North-Eastern Railway Company could be seen in progress—part of an order for 900. A visit was also paid to the welding section where



Heavy machine shop at Head, Wrightson's.

the latest type of welded building made up of mass produced units was inspected.

Those members who so wished could visit the Research Department or any specialised item at the other plants at Stockton-on-Tees. No. 2 Works, the Stockton Forge, is entirely devoted to mining machinery (principally for export) for gold, copper and other metalliferous mines. It also has a section for coal treatment. No. 3 Works, the Stockton Steel Foundry, produces Carbon and Manganese steel by the Tropenas process. No. 4 Works, the Egglescliffe Foundry; where production is confined to heavy iron castings up to 40 tons, including the very large sized ingot moulds.

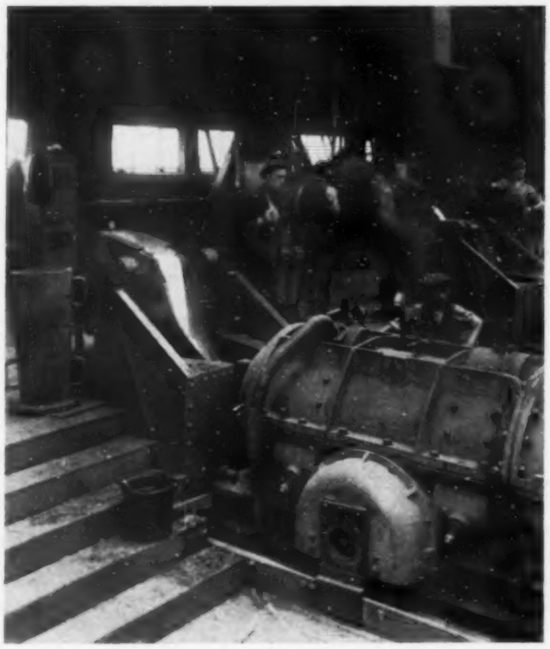
The Ormesby Iron Works of Cochranes' (Middlesbrough) Foundry Ltd.

THE Ormesby Iron Works, which were visited by members, were first established in 1854 for the manufacture of cast-iron pipes. These were produced by sand-casting, which until the Stanton Company adopted and developed the Delavaud process of centrifugal casting, some 15 years ago, was the only practical method of production. This latter pioneer work resulted in the commercial production of centrifugally cast pipe, from which it seemed apparent that pipe casting had entered a new phase and would, in the future, be mainly carried out on the centrifugal principle.

Section of the bridge and constructional yard of Head, Wrightson's.

The management of Cochranes decided to try out the centrifugal system and installed three centrifugal casting machines some six years ago. Up to this time "chill" was unavoidable when casting by the Delavaud process and had to be removed by annealing. It was recognised that the production of castings without "chill" would mark an important advance on previous practice. For a number of years Cochranes' had been developing the Mairy ferro-silicon process and by combining this with the Delavaud process they succeeded in producing a cast-iron pipe which incorporates the advantages of each process.

The Mairy process consists of applying a thin coating of ferro-silicon in the revolving steel mould before the metal is introduced. This deposition forms an insulating surface on the mould, preventing the formation of chill. The resultant casting combines the high tensile strength of the original Delavaud pipe with a greatly increased ductile strength and resistance to shock.



One of Cochranes' pipe-spinning machines at the beginning of the casting operation.

The manufacture of centrifugally-cast pipes is a highly specialised industry which demands the careful planning of a self-contained works. The directors of Cochranes' (Middlesbrough) Foundry Ltd. decided, in view of the recent development of the Mairy process, to re-equip their works with new plant. The old blast-furnaces were dismantled and a considerable portion of the old shops pulled down to provide the necessary space for an entirely new foundry. This was opened in June, 1936 and enabled them to produce pipes ranging from 3 inch to 24 inch in diameter and in lengths of 12, 18 and 21 feet.

The spinners, as the centrifugal casting machines are more generally called, are six in number and are arranged in line side by side with the melting plant. The pipe is cast in an accurately-machined steel mould which is revolved about its own axis through gearing by a motor placed on the outside of the water-cooled casing. The mould is supported by a number of friction rollers with bearings on the inside of the casing. Grease-cup lubrication is effected from the outside of the casing. Through the annular space between the casing and the cylinder, water is circulated at a constant temperature and pressure. The casing, with its revolving mould, is traversed to and fro along its slightly-inclined bedplate by means of a

hydraulic cylinder. Metal is fed into the mould by means of a cantilever trough and a tilting ladle.

Since there is no "chill" to be removed, the passing of the pipes through a normalising furnace is carried out solely with the purpose of relieving any initial strains, and also converting the structure of the iron to a tough condition. The furnace is heated by clean producer gas, supplied by the central producer plant of the works.

The pipes are rolled through the furnace at a predetermined speed regulated by means of a chain conveyer fitted with heat-resisting steel fingers which keep the pipes correctly spaced. The heating is arranged on the counter-flow principle, ensuring peak economy and the correct heating cycle for the pipes which pass through pre-heating, soaking and cooling zones respectively. The waste gases leaving the furnaces are divided into suitable proportions so as to pass part through a gas recuperator andt he remainder through the pipe reheating stove and under the dipping tanks.

From the outgoing side of the normalising furnace the pipes are rolled on to a transfer carriage and placed on the gantries serving the grinding and testing machines.

Some of the spinning machines at Cochran s'.

One section of these gantries is carried on a weighbridge, each pipe being weighed and examined before passing on to the battery of grinders by which the pipes are scrubbed and cleaned inside.

The pipes are then tested hydraulically and are passed on to the reheating furnace, which brings them up to the correct temperature for dipping. The dipping tank is supported on a multiplicity of walls, which form the sides of heating flues and are arranged to give a uniform heat over the full length and width of the tank. Beyond the dipping tank the pipes are loaded up for despatch or passed into stock as the case may be.

Though a works of this nature does not lend itself to extensive mechanisation, it has been possible to arrange that pipes pass through the works with a minimum of handling, and the visitors were impressed by the evidences of careful planning and control which give uninterrupted production of pipes of uniformly high quality.

The test house at Cochranes'.

The Tees Side Bridge Engineering Works Ltd.

ONE of the early engineering companies formed on Tees-side was that founded in 1850 under the title of Gilkes and Hopkins, and later known as The Tees Side Iron and Engine Works. Under this title the bridge and constructional department was developed, and the firm ultimately

18-ton coal charging lorries built by the Tees Side Bridge and Eng. Works, Ltd.

took the name The Tees Side Bridge and Engineering Works Ltd. In the early period of its career this Company was mainly engaged in building blast-furnace plants, puddling furnaces, etc., and, with the rise of the steel industry, was responsible for the building of a large portion of the local steelworks' plants.

The bridge and constructional department now occupies 15½ acres of land, and the whole of the works are entirely modern in constructional details, lay-out and equipment. In the constructional department there are eight bays, varying in span from 50 ft. to 90 ft. and in length from 175 ft. to 1,000 ft., each bay being served by one to four electric overhead travelling cranes (16 in all) having lifting capacities of from 10 to 25 tons. The works are replete with every type of machine tool for the efficient and rapid production of bridgework, etc., and are served by adequate railway sidings. There is an up-to-date smith's shop, equipped with electrically driven drop stamps and steam hammers, hydraulic presses, etc., the work generally manufactured in this shop being wagon forgings, buffer rods, drawbars, etc. There is also a well-equipped machine shop, with slotting, drilling, planing, milling machines, lathes and other machine tools.

The Tees Side Bridge and Engineering Works Ltd. were among the earliest iron and steel bridge building firms, and their name is associated with some of the best known bridges in the British Empire. Since the war the firm have undertaken for the Admiralty and leading oil companies the fabrication and erection of steel tanks for oil storage; steel wireless and television masts for Broadcasting Corporations, and for Marconi Wireless Telegraph Co.; transmission towers for electrification schemes; and the building of large cinemas and garages. In connection with the transmission towers, for which thousands of tons of steel were supplied, the firm laid down new pickling and galvanising plants capable of pickling and galvanising 200 tons of steel sections weekly.

As they were well to the fore in the construction of the early ironworks and steelworks, so now they are taking an active part in the modernising of ironworks, steelworks and other plants, and, in conjunction with Messrs. Simon-Carves Limited, of Stockport, are supplying modern coking plants up and down the country as well as for export. Examples of the work supplied for such plants are: coke-oven doors and frames (of the Wolff patent self-sealing type), coal-charging cars, coke-quenching cars, coke guides and door extractors, scrubbers, coolers, mains, tanks, etc. During the last five years, this firm has supplied over 1,600 sets of coke-oven doors and frames of the Wolff type, these having been supplied for Russia and Turkey, as well as many firms in this country.

The firm has laid down and equipped an electric-welding shop where the fabrication of all types of constructional steelwork is carried out by electric arc welding. There are now 15 welding machines, and the welding carried out has been of a varied nature: very light framing, tubing of every description, light gauge and up to ⅝ in. thick for blast-furnace and steelworks service; tar stills, petrol tanks, water seal valves.

The output of the foundry is about 1,000 tons per week, made up of ingot moulds, repetition castings, chairs, brake-blocks, axleboxes, etc. Incorporated in the foundry department is a key shop, where steel railway keys, steel-plate sleepers, steel clips for fastening flat-bottom rails to steel sleepers, are manufactured. This shop is complete with eleven mechanical punches and presses, capacities from 60 tons to 400 tons, and these presses can be used in the manufacture of small stampings weighing up to, say, 15 or 16 lbs. each.

Vertical electric furnace (Birlec) at Darlington Forge for dealing with very large forgings.

The Darlington Forge Ltd.

THE Darlington Forge, Ltd., commenced on a very small scale over 90 years ago, and has steadily built up an unrivalled reputation for the manufacture of ship structural castings and forgings. Engineers will appreciate the company's association with the *Mauretania*, *Lusitania*, *Aquitania*, *Majestic*, and H.M.S. *Nelson*, and more recently the *Queen Mary*, the structural steel castings for which were the largest ever made in this country or abroad, and included stern frame, shaft brackets, and rudder frame, in all 600 tons of castings.

In addition to ships' castings and forgings, an important side of the work of the Darlington Forge, Ltd., which the visitors noted, lies in the manufacture of high-pressure vessels, boiler drums, and general forgings, together with steel castings for the electrical and general engineering industries.

Owing to the prolonged shipping slump, it became necessary in 1932 to close down the works, and it is probable that this plant, and the experience gained in the manufacture of castings and forgings, would have been lost to the marine and general engineering world had it not been for the action of the English Steel Corporation, who decided to purchase the works and reopen them immediately trading prospects justified such a course, meantime carrying out at their Vickers' Works, Sheffield, such orders as came along for work suitable for Darlington.

Cast steel sternframe at Darlington Forge before fettling.

In January, 1936, English Steel Corporation, Ltd., found it possible to reopen the works at Darlington. In view of the considerable progress which had been made in the application of scientific heat-treatment to large steel forgings and castings, necessitating more accurately controlled temperatures, it was decided to recondition the buildings and equipment and to install additional up-to-date plant, including gas-fired and electrically heated heat-treatment furnaces specially designed for dealing with high-duty steels. When this work is completed, the Darlington Forge will possess a modern and efficient melting department, light and heavy steel foundries, hammer and press shops, machine shops, and a specially designed heat-treatment department.

The steel used in both the heavy foundry and the forge and hammer shops is provided by two acid open-hearth furnaces, one of 60 tons and the other 40 tons capacity, housed in the heavy steel foundry. Two 3-ton stock converters supply the steel for the light foundry.

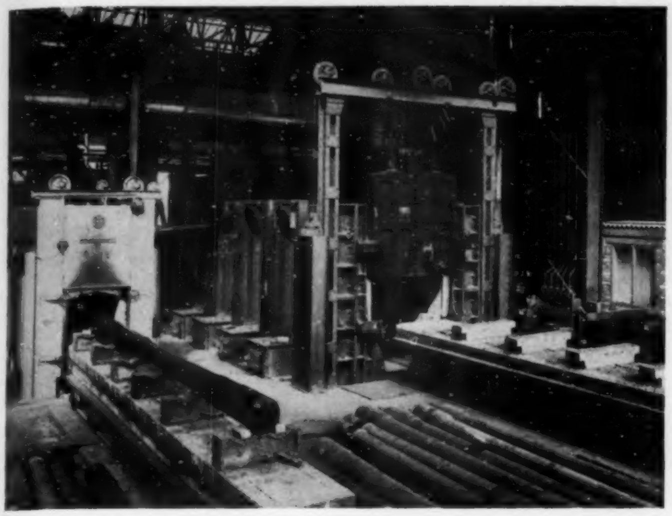
The heavy steel foundry consists of four bays, served by overhead travelling cranes two 100 tons, one 75 tons, two 60 tons, one 50 tons, and one 40 tons. The various sections are fully equipped with drying stoves, moulding machines, and tackle adapted to heavy casting work.

The three bays of the light foundry are served by four overhead cranes, one of 30 tons capacity and three of 15 tons capacity each. The fettling shops are equipped with sand blast, compressed air, and other services.

The forge includes four presses, ranging from 1,500 tons to 3,000 tons, capable of dealing with ingots up to 100 tons in weight, and is served by eight overhead travelling cranes, the largest being capable of dealing with a weight of 200 tons.

The frame shop, with the usual smithy equipment and

Half of a built-up 8-throw forged steel crankshaft at Darlington Forge.



Bogie electric furnace (Birlec) for large forgings and a smaller producer gas-fired furnace at Darlington Forge.

two 40-ton cranes, includes a large cap hammer, used chiefly for the assembly and welding up of large frames which have been forged in sections in the usual manner under a press. A new 4-ton steam hammer is housed in a building, complete with two 10-ton overhead cranes and two air-regenerative producer gas-fired furnaces, provision being made for further hammers and furnaces.

An entirely new heat-treatment department with specially designed furnaces deals with the wide range of castings and forgings produced. The low-level crane track joins up with the press shop, making available existing cranes in this shop, and on the high-level track there is a 20-ton oil-dipping crane, arranged for oil dipping at 300 ft. per min.

The furnace equipment consists of one vertical electric furnace (electrical rating 500 kW.), capable of dealing with forgings 30 ft. long by 2 ft. diameter, installed below floor level in a watertight caisson 17 ft. 6 in. diameter.; one horizontal bogie electric furnace (electrical rating 330 kW.), capable of dealing with forgings 30 ft. long ; five producer gas-fired furnaces as follows : One single-ended bogie non-regenerative furnace, 65 ft. long ; one double-ended bogie air-regenerative furnace, 45 ft. long ; and three single-ended bogie air-regenerative furnaces.

The machine shops, which cover an area of approximately 12,000 sq. yds., for the most part are structures of modern design, equipped with up-to-date machines and tackle suitable for machining the heaviest type of castings and forgings as required in shipbuilding and general engineering. The six shops are equipped with overhead travelling cranes of the following capacity : Two 100 tons, one 60 tons, one 50 tons, one 25 tons, seven 20 tons, and two of 15 and 5 tons. As in the case of the foundries, many jib cranes are installed at various points for localised handling of parts.

The Cleveland Bridge and Engineering Co., Ltd. Darlington

ESTABLISHED sixty years ago, The Cleveland Bridge and Engineering Company Ltd., have carried out the business primarily of bridge-building and also many other types of steel structures such as workshops, power stations, hangars, pipe lines, dock gates, etc. In addition to the manufacture of structures, they are also general contractors and undertake all foundation work and erection of their structures, and have had long experience in river pier foundations, both under compresed air and in the open.

They have built several well-known bridges, including the King Edward Bridge over the River Tyne at Newcastle, the Victoria Falls Bridge over the Zambesi River, and among the more recent bridges are the Lower Zambesi Bridge, 2¼ miles in length, a bridge over the Forth at Kincardine, and a ferro-concrete bridge over the Thames at Chiswick. Apart from bridges, they have carried out such contracts as the Floating Landing Stage for the Port of London Authority at Tilbury, which is 1,100 feet long, power stations for the City of London Electric Supply Co., and the supply and erection of steel pipes for carrying the water supply for the Corporation of Calcutta, the weight involved being 17,000 tons. They have built bridges and other structures in many parts of the world and are at present engaged in bridge-building in India, Brazil and Peru.

Drum and bearing girders for bridge swing-span by the Cleveland Bridge and Engineering Co., Ltd.

The works of the Company cover approximately 30 acres and are situated adjacent to the main line of the L. and N.E. Rly. They comprise all the necessary shops for the fabrication of most kinds of steelwork, and are well equipped for machining many of the fittings for the structural work manufactured. The works are divided into departments according to the operations carried out, and in the material yard the plates, joists, channels, angles, etc., received direct from the mills, are unloaded, checked for size and thickness and flattened and straightened, and the bars and sections are cropped and sawn to lengths. There are more than 70 radial-arm drilling machines in the various shops, and the plates and bars, after being drilled, are assembled or plated and riveted together by hydraulic pressure of 1,100 lb. per sq. inch. An important feature of the firm's work is the practice adopted of only putting sufficient holes in the plates and bars to enable them to be tacked together, and then, when they have been assembled, the holes are drilled through all the component

One of the assembling departments of the Cleveland Bridge and Engineering Co., Ltd.

View of Lower Zambesi bridge from east end built by Cleveland Bridge and Engineering Co., Ltd.

parts at one operation, thus ensuring a perfectly fitting bolt or rivet. Welding is now being extensively employed in structural work instead of drilling and riveting, with the object chiefly of saving weight.

The process of welding is one of the most recent developments in the fabrication of steelwork, and another is the use of oxy-coal-gas for cutting steel plates. The flame is not generally considered to harm the nature of the metal, and it is possible to make a clean and finished cut only $\frac{1}{16}$ inch wide.

The Darlington Rolling Mills Co. Ltd.

FOR convenience of description, the works which were visited may be divided into two parts, viz.: South and North plants.

In the south section is the electric sub-station where power is received—supplied by Darlington Corporation—at 6,200 volts, 50 cycles, 3-phase A.C., and by means of rotary converters and their respective transformers, is transformed to 460 volts D.C. There are also two small transformers for supplying necessary power for lighting and auxiliary plant at 230 volts A.C.

There are two 12 in. three-high mills, which were designed for the rolling of speciality steel sections, which cover a wide range of industries, including the manufacture of steel windows, roof glazing and sections for the motor-car industry. No. 1 mill comprises one 14-in. three-high roughing mill and a finishing train of five stands, which is a 12-in. three-high mill. No. 2 mill consists of one 12-in. three-high roughing mill and a finishing train of four stands, which is a 12-in. three-high mill, the housings for the two finishing mills being interchangeable.

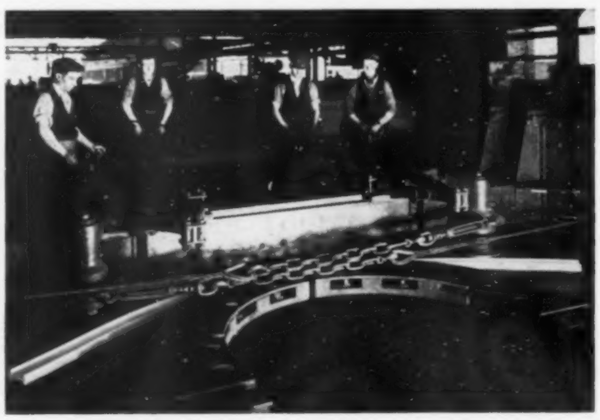
The plant has been specially designed to facilitate easy handling of the rolls and making quick changes possible. The complete housings are lifted from the mills by an overhead crane and placed on re-change housing bedplates where the actual roll-changing and guide-setting takes place.

Each mill is housed in a spacious building with adequate window space to ensure efficient lighting and ventilation. The buildings are equipped with overhead electric travelling cranes. The mills are supplied from one common billet yard, which is served by a 5-ton overhead electric crane with a span of 100 feet.

Each mill is served by a continuous reheating billet furnace, the billets being fed into the furnace by an electric billet pusher. The furnaces are pulverised fuel fired from a "central system" pulverised-fuel plant. Each is equipped with a mechanical cooling bank for handling of the finished material. A noteworthy feature of the live roller gear run-out to the cooling bank is the independent motor drive for each roller. The shears in each mill are arranged in line with the cooling bank out-going roller gear to facilitate handling of the sections. All sections produced in these mills are passed through cold-roller straightening machines.

At the north plant a 16-in. mill is installed which is engaged in the rolling of light rails, corrugated plates and colliery arches, also special sections. The mill, which is two-high reversing, is designed for three housing stands, one 16-in. roughing stand, one 16-in. intermediate roughing stand and one 16-in. finishing stand.

Lifting out a complete mill housing at Darlington Rolling Mills, Ltd.



Arch bending machine at Darlington Rolling Mills, Ltd.

Interior of 12-in. mill building at Darlington Rolling Mills, Ltd.

Engineering and Marine Exhibition

The Engineering and Marine Exhibition and the co-incident Foundry Trades' and Welding Exhibitions just opened provides a diversity of interests, well illustrative of metallurgical progress, and should prove equally valuable to those producing or offering products or services and to those many who are seeking the most satisfactory products and sources of supply.

THE Engineering and Marine Exhibition, which opened at Olympia on September 16 and continues until October 2, incorporates the Foundry Trades' Exhibition and the Welding Exhibition. It is evident from the information available that this year's exhibition will be of exceptional and comprehensive interest.

Of the many exhibitors, we are able to give details of the following companies and their products or services :—

Birmingham Electric Furnaces, Ltd.

The Birlec exhibit concentrates attention on tool room and melting furnaces. In addition, a very extensive display of photographs, literature, and sample products effectively represents the extremely wide range of Birlec furnaces, for every heat-treatment and melting application, the size of which precludes installation on the stand.

The unique "Certain Curtain" controlled atmosphere furnaces, for hardening high-speed and alloy steel tools, are exhibited in the latest improved and simplified form. New constructional methods give improved appearance and convenience in use, while revised design has made the atmosphere control system both simpler and more accurately adjusted.

Birlec high-velocity air-circulation furnaces, as widely used for tempering and other low-temperature heat-treatment operations, are represented by a model of convenient size for tool-room use. The charge progress recorder, which enables heating and soaking times to be measured accurately, is shown with this exhibit.

Of great interest to the Foundry Section of the Exhibition is the new Birlec Detroit furnace, which will be shown on this stand. This type of indirect arc rocking furnace has already won recognition of its exceptional qualities in both ferrous and non-ferrous melting, and the new model incorporates several important developments, including a new design of shell and the patented automatic rocking control device. The latter gives exceptional flexibility and a range of control which permits satisfactory metallurgical conditions to be obtained and repeated exactly for every type of charge.

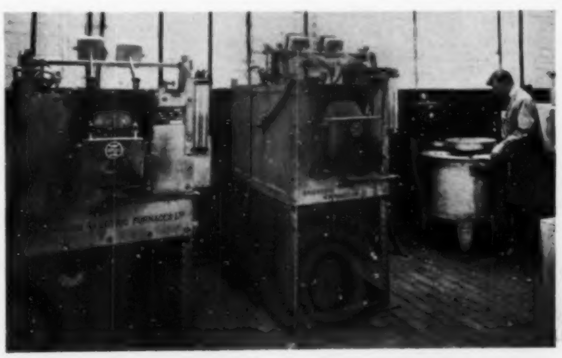
The English Electric Co., Ltd.

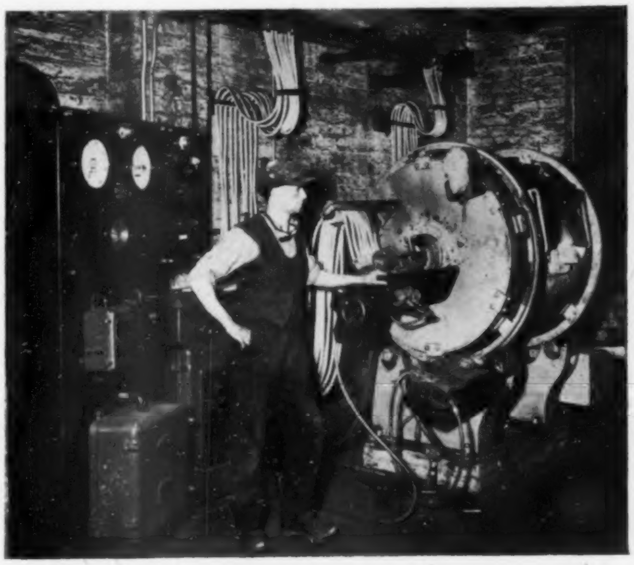
A representative range of this company's A.C. arc welding equipment is exhibited and practical demonstrations given at intervals.

The Multi-Operator equipment comprises an oil-immersed, self-cooled transformer for supplying three welding regulators capable of welding up to a maximum of 300 amps. Insulated and mechanically interlocked plug and socket connectors connect the transformer to the regulators.

The welding regulators are of the oil-immersed, self-cooled type. An externally operated switch in the cover of the regulator allows current values to be selected to suit the electrode being used, either 24 or 36 steps are provided, according to the size of the regulator. Three sizes are to be shown : 400-amp. equipment, with current range from 95 to 400 amps. in 24 steps ; 300-amp. equipment with range from 35 to 315 amps. in 36 steps ; and 200 amp. equipment, with range from 17 to 210 amps., of the universal type, and suitable for taking electrodes from 20-gauge to 4-gauge.

High-speed and alloy steel hardening furnaces.





Birlec rotary electric melting furnace.

A light-gauge welding equipment of the air-cooled type will also be shown, this having a current range from 12 to 56 amps., regulated by vernier control and suitable for welding of light materials from 20 to 16 gauge. This is a portable unit.

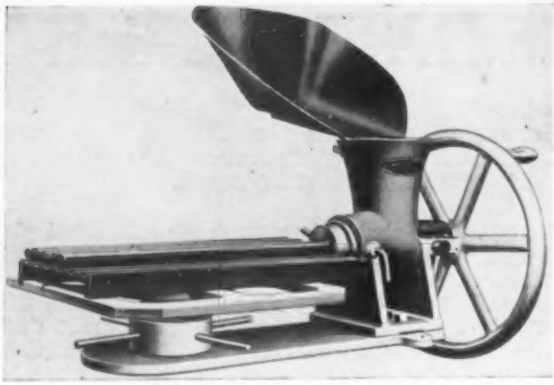
Finally, there is a welding attachment, comprising a tapped choke, for use in conjunction with the heavier current welding equipments and for reducing the current to very low values, so that very thin gauge materials may be welded successfully.

Thos. Firth and John Brown, Ltd.

A selective range of the products of this company, as supplied for marine engineering and general purposes, and for which it has earned a world-wide reputation, form an integral part of this display.

The central feature of the stand is a large hollow-forged seamless boiler drum, together with crankshafts and other large marine forgings, similar to those supplied for R.M.S. *Queen Mary* and leading shipping companies.

The stand also displays a group of die blocks, castings, springs, cast steel pilger rolls, hardened steel rolls in various finishes, and a wide range of engineers' small tools.



A Fordath hand-operated multiple rotary core machine, for making cores up to 3 in. diameter.

The latter consists of twist drills, reamers, milling cutters, butt-welded lathe tools, hacksaw blades, files, and visitors will have an opportunity of trying out the merits of the "Millenicut" file on the demonstration bench. The models of the Firth-Brown twist-drill point grinding machines, and the Firth-Brown "Hardometer" testing machine are also on view, and a staff of technical experts will be in attendance.

The Fordath Engineering Co., Ltd.

A range of "Glyso" core oils and compounds is shown, and technical and demonstration staff advise on any sand mixtures for all types of metals, from alloy steels to the latest types of light aluminium alloys, and also on any matters relative to foundry problems.

Multiple rotary core machines, both power and hand-driven, and of "Junior" and "Senior" types, with dies ranging from $\frac{1}{8}$ in. to 6 in. in diameter, are shown, together with typical sections of cores produced from these machines. The main features of these machines are speed of production, accuracy of production and simplicity.

"Rotoil" Mixers.—The "Senior," "Junior," and laboratory types are exhibited, and the mixing of all kinds of sands, oils, compounds, etc., is their function. Absolute silence is a feature.

The capacity of these types is 3 tons, $1\frac{1}{2}$ tons, and 3 cwt. per hour respectively of any kind of oil-bonded sand. Upkeep is negligible and all are driven by totally enclosed gearing.

Core Cut-off Machine.—This machine trims cores accurately and quickly to any desired length, by means of a carborundum wheel. It is driven by a $1\frac{1}{2}$ h.p. motor through a belt running in a V-pulley. The carborundum wheel is adequately guarded, and for the determination of lengths of cores, suitable stops are fitted to an incorporated slide.

Sand Driers.—Two types are shown, one having an output of 10 tons and the other 5 tons per day.

Simplicity of construction, economy in running and upkeep costs and minimum of handling are the main features.

Refractory coatings for cores and moulds, including steel-mould paint, bath-mould dressing, blackings, etc., are on view.

W. and T. Avery, Ltd.

Prominent amongst the testing machines exhibited by this firm is a self-indicating universal testing machine suitable for carrying out all the standard tests, and special features are the clear indication of the load in view of the operator manipulating the single control wheel, its compact construction, and its lightness and portability.

Two hardness testers are also shown. The first is a self-indicating machine which has been specially designed for rapidly determining the Rockwell hardness of materials in terms of standard penetration. A direct numerical reading is given on the dial, eliminating subsequent measurement and calculation. A complete test can be carried out in approximately 10 seconds, and as the mark left by the penetrator is slight, the machine is suitable for production testing of finished articles. The other machine is designed for carrying out Brinell hardness test, and is guaranteed accurate to one-thirtieth of 1%.

An impact testing machine is exhibited which is the standard machine for carrying out "Izod" impact test specified by Government departments and important engineers, while another exhibit is a fatigue testing machine, for applying bending stresses upon metals. A new addition to the range is a wear and lubricant test machine, by means of which the relative wear of metals can be ascertained from the dimension of an impression made by the periphery of a rotating wheel of one metal coming into frictional contact with a stationary flat sample of another metal. The principle is much the same as where the impression of a ball or diamond cone is taken as a measurement of hardness.

G.W.B. Electric Furnaces, Ltd.

The electric furnaces manufactured by this company are too large to be shown at this exhibition, and a series of photographs showing various types erected recently are displayed. In addition to six such photographs, samples of Eternite case-hardening compound and of quenching oils, etc., are shown. The photographs include :—

A Large Continuous Chain Conveyer Type Furnace.—For heating of aluminium alloy billets, prior to extrusion in the form of tubes, light sections, etc. This is one of the largest electric furnaces of its type in this country, and every operation entailed in its use is automatic.

Bell Type Bright Annealing Furnace.—This is for bright annealing wire at temperatures up to 1,100° C. in a protected atmosphere obtained by the introduction of a suitable gas.

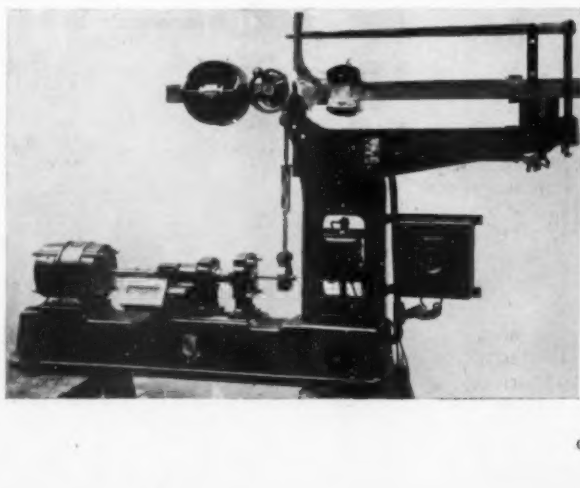
A Continuous Wire Patenting Furnace.—This is the first electric furnace of its kind to be made in this country. The furnace works at temperatures up to 1,000° C., and is divided into four separately controlled zones. The output is approximately 5 cwts. per hour.

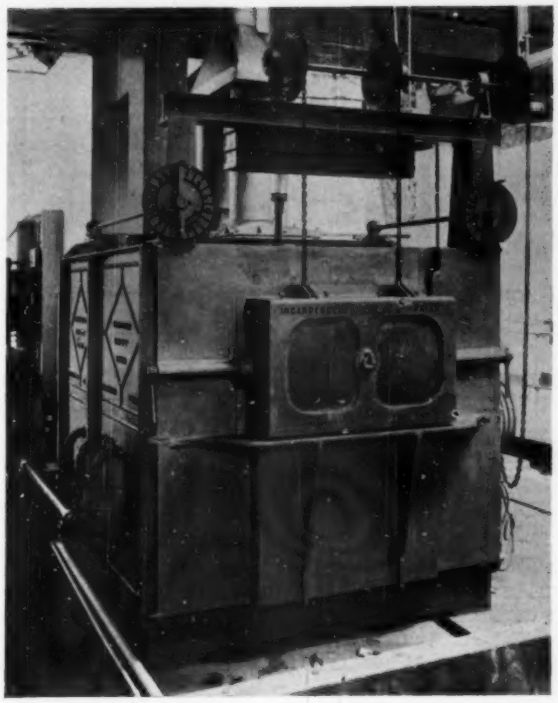
A Continuous Type Slat Conveyer Furnace.—This is used for annealing cast-iron motor-car pistons prior to machining. The output is approximately 750 pistons per day of eight hours, each piston weighing $1\frac{7}{8}$ lb.

Roller Hearth Furnace.—This is used for the heat-treatment of aluminium billets prior to forging, stamping, etc., the billets being conveyed through the furnace on heat-resisting steel rollers.

Two Charging Machine Type Box Furnaces.—These are used for annealing coils of bronze and brass strip, a clean anneal being obtained. They incorporate the Gibbons-Van-Marle charging machine, which is manufactured by the associated company, Messrs. Gibbons Bros., Ltd.

Avery fatigue testing machine.





A heat-treatment furnace exhibited by Incandescent Heat Co., Ltd.

Hancock and Co. (Engineers), Ltd.

This company are manufacturers of machines for profiling, straight and circle cutting, parting-off, etc., and of oxy-coal-gas cutting plants. Their four exhibits are the Auto Simplex machine (which is being exhibited publicly for the first time), a triple head machine which also has not previously been exhibited, the 2A direct cutting and profiling machine, with a cutting area 42 in. × 30 in., and the "Circaline" portable automatic straight line and circle-cutting machine.

The Auto Simplex, with twin annular cutting head, is an all-purpose machine, suitable for cutting single, or a few only, parts from a drawing, accurate and intricate shapes, singly or in quantities from a wooden template, or from a channel templet, or accurate shapes of large area from a strip aluminium templet, regular or irregular shapes, discs or holes up to 40 in. diameter, straight lines or circles at a bevel up to 45°, and various other applications, including rings cut inside and outside simultaneously, vertically, or at a bevel. The machine is fitted with two motors, one for driving the standard tracer head and the other for driving the annular head; the latter is easily detachable, and can be replaced by a standard 2 in. burner with or without bevel-cutting head.

The triple-head unit is a Universal Simplex triple-head oxygen cutting machine, with three cutting burners, and works from a drawing, strip metal or wooden templet. It has a circle and straight cutting attachment. The cutting area for each burner is 24 in. × 12 in., and metal up to 8 in. thickness can be cut. The triple-head unit is capable of a large output of reproduction parts. All burners have a single control for both heating and cutting oxygen, and will start up or stop simultaneously. The electric tracer has a constant speed A.C. or D.C. motor, with infinitely variable gear for speed control.

The Sheepbridge Stokes Centrifugal Castings Co., Ltd.

Typical components in special alloy cast irons, manufactured either by their centrifugal process of casting where cylindrical shapes are required, or as sand castings for more complex shapes or the larger sizes of cylinder liners. Amongst the more important of these special irons are the following :—

"Centrard" (nitrogen hardened), for resistance to abrasion, surface deformation and corrosion. Brinell hardness 850 to 950.

"Centricast" Mark II. chrome alloy iron for wear resistance, suitable for oil-hardening where thin sections are required.

"Centricast" Mark III. nickel chrome alloy iron, or Mark IV. nickel alloy iron, for wear resistance and high strength, suitable for oil-hardening where thick sections are required.

Examples of these materials will be shown as castings and also as finished machined cylinder liners for all types of Diesel, superheated steam or petrol engines, including large marine sizes.

Valve seat inserts in special alloy irons and in stellited steel will be shown, with tools for fitting the company's Centrilock type.

Centrifugal cast and sand-cast piston ring drums, and special die cast alloy iron rod will be shown. Other exhibits will include Hypocrode, Nicrosilal, Silal, Ni-Resist, and other special alloy irons for heat- and corrosion-resistance, with samples of annealing boxes, firebars, furnace parts, and pump parts.

The Mond Nickel Co., Ltd.

Animated models, dioramas, and stereoscopic pictures will be used on this stand to explain many of the advantages and applications of nickel alloys.

For example, one diorama illustrates mining equipment, including the use of nickel steel in mine cages. The exhibit emphasises that strength is not sacrificed because the structure is relatively light; greater loads can be carried each journey or a lighter cable used for the same load. The prototypes of the cutters and loaders in the model employ nickel alloy steels to withstand the heavy stresses and abrasion met with in service, and Ni-Tensyl, a high-strength nickel cast iron, is used for large winding drums, similar to the one in this display.

A model machine shop effectively demonstrates the use of nickel cast iron and nickel alloys steels in machine-tool equipment.

The nickel-aluminium magnet steels are represented by an ingenious model of an aeroplane floating in the field of force above a nickel aluminium steel magnet, and several other magnetic models designed to illustrate the power of nickel-aluminium steel magnets afford interesting exhibits.

A stereoscopic picture provides a striking comparison between the loads which may be carried by Ni-Tensyl and by ordinary cast iron. The two models illustrated typify the ease with which a casting of thick and thin sections may be made in Ni-Tensyl, and the unsoundness and chill which may result when a similar casting is made in ordinary cast iron.

Another model illustrates the superior wear resistance of nickel cast-iron cylinder liners when used in commercial and other vehicles which make short journeys with frequent stops.

An animated model includes a railway train, introduced to stress the growing importance of nickel alloys in railway engineering—nickel-steel boilers where high pressures are required without increase in boiler weight, nickel alloy steel reciprocating parts, and Monel staybolts.

A stereoscopic picture of two connecting rods, one of carbon steel and one of nickel alloy steel, affords another interesting comparison. Each section has the same strength per unit length, and each is suspended from a spring balance to show clearly the 30% saving in weight effected by the use of nickel alloy steel.

Other stereoscopic displays include a picture which illustrates the interesting fact that nickel cast iron has a certain degree of malleability, and a colour stereoscopic picture of the internal sections of used brass and nickel-copper condenser tubes.

Stewarts and Lloyds, Ltd.

Samples of foundry, forge, basic and special pig irons will be on view, the brands being " Lloyds," " S and L," " H.M.," and " S.V.H.," and their range of analysis makes them very suitable for foundry trade purposes such as light castings, machinery castings, and castings for the engineering, hollow-ware, and building trades.

Two working models of springs made from pig iron will show the physical qualities of the brands of Stewarts and Lloyds' manufacture, while typical examples of products manufactured from them demonstrate their adaptability to foundry requirements and the excellent surface they provide for enamel finishing. These consist of Norfolk sink, heating stove, moulded gutters, luxury bath set, Sussex type gas cooker, coat of arms decorated in heraldic colours, gas fires, gas cookers, and domestic heating boiler.

A model of the locomotive, *Princess Royal*, typifies the use of " S. and L." products on railways, as their pig iron and boiler tubes were used in its manufacture.

Models are also exhibited of a steel chimney, a slag ladle supplied by E. N. Wright, Ltd., and of the large " Digger " built by Ransomes and Rapier, Ltd., for Stewarts and Lloyds' mines at Corby.

Raw materials for foundry use comprise Northamptonshire limestone and Lowick ganister, and there are also shown the iron ores from which the pig iron is made, and various qualities of slag, which is broken and graded for roadmaking, filter beds, ballast, and farm and estate work.

In addition, there are C.I. helical wheels, steel castings, steel sections, and tube strip from the S. and L. Foundries and Steel Works.

Electromagnets, Ltd.

Magnetic separators, lifting magnets, clutches, chucks and brakes will be shown on this company's stand.

A rotary drum type separator for dealing with mixed ferrous swarf, and a new type of agitated chute separator for the extraction of finely sub-divided iron from non-ferrous materials prior to smelting should be two details of particular interest to the metal trades.

A useful general purpose magnetic extractor will be shown. This consists of a mild steel hopper with a low feed height, a slow-moving band conveyer passing over a patent " Rotaflux " magnetic pulley. The non-ferrous material falls by gravity to the front of the machine, and the iron is extracted and discharged underneath the pulley, away from the cleaned material. This machine should be of decided interest to rolling mills and to brass founders who make arrangements with their customers to take back scrap and residues.

Also, a 36-in. diameter lifting magnet will be exhibited, handling large castings up to 30 cwt. Patent chute-type separators for the extraction of fine iron and magnetic oxides from enamel, gun-cotton, glaze, slip, and similar materials will be included.

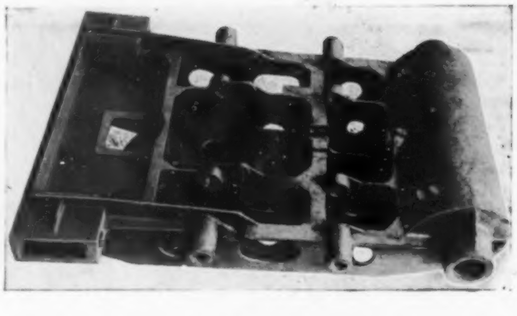
These equipments will be demonstrated under actual working conditions.

Sterling Foundry Specialities, Ltd.

The exhibit will comprise a representative selection of Sterling rolled steel moulding boxes of various styles and sizes, for iron, brass, steel and aluminium foundries, and a range of Sterling wheelbarrows, suitable for foundry and other industrial purposes.

Sterling moulding boxes are made from a rolled steel bar of a special patented section, the shape of which has been designed to afford great strength and rigidity and minimum weight. The lugs and handles and other fittings on Sterling boxes are strongly welded to the box.

Sterling boxes are made to suit all purposes, and in sizes from 9 in. square by 2 in. deep each part, up to 72 in. square by 16 in. deep each part ; also circular boxes from 12 in. diameter to 72 in. diameter. They are all made to customers' specifications as regards the exact length and breadth of the box, and can be either supplied with fixed pins or arranged for use with loose pins. When required, the pin centres will be drilled to suit customers' existing pattern plates or odd-sides.



Bogie for excavator, made of K.L. " Stronger Steel."

Sterling wheelbarrows embody a number of important improvements, such as the ten-spoke wheel, the pre-lubricated axle, and the construction of the legs, which are fitted with renewable shoes.

The Sterling general purpose foundry barrows are made in 20 variations, with capacities from 3 cub. ft. to 6 cub. ft., and having trays of various gauge thicknesses. There are, in addition, special purpose barrows with trays suitable for coal, coke, and pig-iron. All parts are standardised and made interchangeable for repairs and replacements.

The Tungum Sales Co., Ltd.

This company show their alloy " Tungum " in the forms of rod, sheet, tube, wire and ingot. It is then taken to the further stages as propeller shafts, containers, such as petrol tanks, tubing as specified by the Air Ministry under the appropriate specification (the several Tungum specifications are DTD 253, 253A, 283, 319, and 323), gauze, screens and castings ; and examples of stampings, pressings, forgings, spinnings, springs, screws, bolts and nuts will also be exhibited.

It is claimed for this alloy that it possesses a combination of properties seldom found in any one metal. It is non-magnetic, has high resistance to corrosion, is ductile, and easily machined and worked. It has high thermal conductivity, forms an excellent bearing metal, and has a high resistance to metal fatigue.

Kryn and Lahy (1928), Ltd.

Several types of castings covering a wide variety of industries will be displayed, the chief of which will be ships' davits, pressure castings (including steam chests), railway locomotive castings, excavator castings, also traction motor frames and other components of electrical machinery.

Examples of the use of K.L. " Stronger Steel," one of the firm's main productions, occupy an important part in the steel castings exhibit. It will be recalled that this material combines the strength of high tensile steel with the ductility normally associated with mild steel. The makers give the following threefold guarantee :—

Tensile strength, 35–40 tons per sq. in.

Elongation, at least 20% on the standard B.S.S. test-piece.

Cold bend test, to an angle of at least 120° on the standard B.S.S. test-piece.

A railway exhibit of a somewhat unusual nature consists of a wheel for a main-line locomotive, which has been subjected to a destruction test. The wheel was dropped between spokes at points 90° apart on to a concrete and armour-plate foundation, and the height of the drops was gradually increased up to the limit of the crane—namely, 18 ft. At the maximum height 24 drops were made, and after this formidable punishment, causing the wheel to assume an almost square shape, no trace of fracture could be found.

Wild-Barfield Electric Furnaces, Ltd.

A wide range of furnaces are covered by the exhibits on the stand. It is not, of course, possible to show all types of furnaces and new developments which have taken place recently, but equipments not shown are illustrated by a series of photographs taken of installations in various works.

Small muffle furnaces for use in laboratories and works where only occasional hardening is done, are represented in various sizes and types, such as horizontal rectangular and oval sectioned muffles, and also tube and vertical furnaces. These furnaces have a wide application, and are in extensive use owing to their lasting qualities coupled with low initial and running costs. In addition, soldering-iron heaters will be on view. These heaters are very useful and economical to run and clean in operation, as there are, of course, no fumes of any description. For the correct hardening of carbon and low alloy steels the Wild-Barfield electro-magnetic furnace still holds the field, and will be exampled here by a vertical furnace.

Vertical furnaces with forced air circulation will be shown in two standard sizes, one a small production equipment with the charge progress recorder for controlling the furnace temperature and indicating when the charge is up to temperature, which saves much valuable time when heat-treating large quantities of work. A smaller model of this type of furnace is also shown. This furnace is generally similar to the larger furnace mentioned above, but of somewhat simpler construction, and consequently sells at a price within the capacity of most pockets. These furnaces can be used for all types of low-temperature heat-treatment below 700° C., such as tempering, secondary hardening of high-speed steels, annealing non-ferrous metals, solution and precipitation treatments of aluminium alloys, etc.

For higher temperature treatments up to 1,150° C. will be shown a horizontal batch-type furnace with patented "Tubular-Hairpin" heating elements. For slightly lower temperatures "Heavy-Hairpin" elements are employed.

Two examples of electric high-speed steel hardening furnaces will also be shown. One will be a toolroom furnace and the other suitable for production work. In the larger one the preheating and high-temperature chambers are entirely separate, each being self-contained and fitted with automatic temperature control. In addition, positive atmosphere control is incorporated by the "Counterscale Curtain" equipment, which effectively prevents scaling or decarburisation and gives a clean result.

High Duty Alloys, Ltd.

This company will show typical examples of the "Hiduminium" R.R. series of high-tensile aluminium alloys in cast and wrought forms, and typical micro and macro sections of "Hiduminium" alloys. One of the most interesting of a range of products of particular interest will be the application of "Hiduminium" R.R. 56 for wrought big-end bearings.

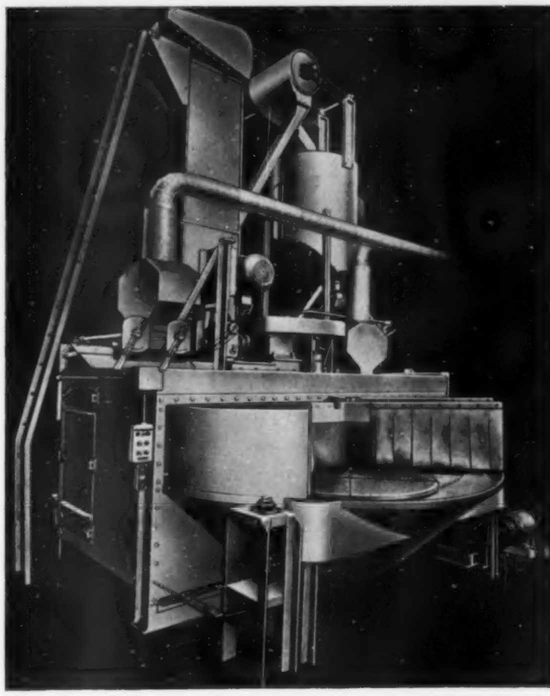
There will be examples of extruded sections and of tubes in both anodically treated and anodically coloured conditions.

Sand-cast Diesel engine pistons in "Hiduminium" R.R. 53 and other Diesel engine pistons in "Hiduminium" R.R. 59, which is a wrought alloy, will be exhibited. Also for Diesel engine application are examples of cylinder head and crankcase castings, these being in "Hiduminium" R.R. 50.

Tilghman's Patent Sand Blast Co., Ltd.

Interesting developments in sand/shot blast machines and in the Wheelabrator (airless abrasive cleaning) for foundry equipment are shown by this firm, together with a variety of their standard air compressors.

In addition to the Wheelabrator "Tumblast" machine shown, there is also an important development known as the "Tablast," for which Messrs. Tilghman's have acquired the sole right of manufacture and sale throughout the British Empire, but excluding Canada.



Modern sand-blasting equipment by Tilghman's.

The air compressor exhibits include a double-acting, two-stage inter-cooler type, with a capacity of 1,000 cub. ft. of free air per minute, and suitable for a pressure up to 120 lb. per sq. in.; a typical example of a range of machines delivering from 400 cub. ft. to 3,000 cub. ft. of free air per minute. There will also be a single cylinder low-pressure, double-acting machine, designed to deliver 120 cub. ft. of free air per minute at a pressure of 60 lb. per sq. in., and representative of the range of machines delivering from 100 cub. ft. to 800 cub. ft. of free air per minute.

The 30–200 cub. ft. per min. range of machines will be represented by two compressors of the single-acting type, having a capacity of 50 cub. ft. of free air per minute each, and a single-acting compressor is taken from the range of machines which deliver from 4 cub. ft. to 25 cub. ft. of free air per minute, being suitable for pressures up to 100 lb. per sq. in.

The Non-Ferrous Die Casting Co., Ltd.

The castings on view will be representative of those used in most industries, and are produced by the gravity or pressure process in brass, al-bronze, zinc-base alloy, various aluminium alloys, and tin-base alloy; sand casting in brass, gunmetal, phosphor bronze, and aluminium alloys.

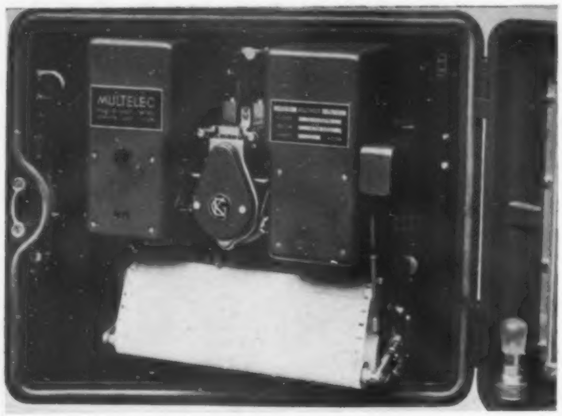
There will be typical examples of die castings as used in the motor, aircraft, and electrical trades, and many examples from other industries, these ranging from small intricate parts, such as brushgear and carburettors to large brass castings, 2 ft. long and weighing about 15 lb., these being used in dairy and refrigeration plant.

George Kent, Ltd.

A complete panel will be shown, carrying the necessary instruments for the efficient operation of a modern boiler, and including recorders for conductivity, *p*H, CO_2, steam-flow, water-flow, draught, pressure, etc.

The Multelec, a multiple-point recorder which can be used for measuring temperature, *p*H, or conductivity, will be exhibited functioning as a *p*H recorder.

Ring-balanced recorders, which have proved very successful and popular in the iron and steel industries, will be shown in various combinations of recording, integrating,



The Kent "Multelec" Recorder.

and indicating units. Also, a ring-balance flow controller will be on view.

Other exhibits include Venturi recorders for water and sewage; positive rotary meters for water, oil, and petrol; rotary steam meters for small mains; diaphragm-operated steam meters for ships; and the well-known K.M. type differential-operated type flow recorder.

It is claimed for the Kent Multelec that it is a versatile instrument, capable of recording and controlling a number of conditions. Its advantages include: Potentiometric principle, ensuring perfect automatic temperature compensation; indifference to high or varying line resistance; frequent automatic current standardising; robust galvanometer; high accuracy, independent of galvanometer characteristics; 1/1000th of an inch galvanometer deflection instantly detected and recorded; high-frequency measuring cycle, ensuring immediate recording of any change; and ample width of chart. Actually, the chart width is 10 in.

The special design of this instrument allows a control unit to be added without difficulty. The standard A.C. motor operates at 110 volts 50 cycles. For other voltages a transformer is required, and for frequencies other than 50 cycles a motor generator must be provided. The standard D.C. motor, together with the resistances in the instrument, will operate between 200 and 250 volts.

Potentiometric temperature measurement and control by Multelec is a valuable aid to the correct operation of towers, kilns, ovens, all types of furnaces, stills, and other processing units. The *p*H value denotes the effective acidity or alkalinity of a solution, and is determined by measuring the concentration of the hydrogen-ions or hydroxyl-ions which it contains. The Multelec will measure this value to within 0·025 *p*H, and on automatic control will actuate the plant for a change of 0·05 *p*H. Various types of primary element are available, the one most commonly used being the tank-mounting antimony-calomel unit. The Multelec, functioning as a Wheatstone Bridge, will detect, record, and, if necessary, control electrolytic resistance. Various types of conductivity cell are available.

Bradley and Foster, Ltd.

This firm are well known as manufacturers of high-grade refined irons, and also of chilled shot and grit. Another department of this firm specialises in commercial heat-treatment.

In addition to refined pig irons treated by a patented degasification process, their products include a complete range of refined malleable pig irons, cylinder irons, and refined alloy pig irons containing chromium, nickel, copper, molybdenum tungsten, to suit the requirements of individual specifications. The firm manufacture in ingot form austenitic irons of the Ni-resist, Nicrosilal, and No-Mag types. Nicrosilal and Silal pig irons are manufactured under licence from the British Cast Iron Research Association. High-silicon acid-resisting alloy is also manufactured in ingot form. Two other brands of refined iron manufactured by this firm are worthy of special notice. These are high-carbon-steel pig iron for use in the manufacture of semi-steel and also of high-strength castings in inoculated irons and blended "All-Mine" pig irons, which match exactly the inherent properties of cold-blast pig irons.

All varieties and grades of chilled shot and grit used in the various operations of cleaning castings, sand blasting, enamelling, rock boring, well drilling, and stone cutting.

All types of heat-treatment for the trade are undertaken. This department is equipped with the most modern furnaces, and is also the Birmingham and district licensed centre for the nitrogen hardening process.

Henry Wiggin and Co., Ltd.

The most important exhibit is a segment of a turbine rotor fitted with the new integral root Monel blading recently developed. The root is made with a smooth-flowing grain structure, and there can be no weak spot between the root and the blade. Grooves are milled in the root to fit into corresponding grooves in the rotor rim, and each blade is inserted and locked in position by turning through 40–45°.

Other exhibits include a Monel pickling crate for steel sheets prior to enamelling, an all-welded crate, welded Monel link chains for slings in the pickling of steel rods and tubes, crew's wash basin, specimen Monel propeller shaft, miner's lamp, aircraft exhaust manifolds of Inconel, a filtrator unit with Monel ball float and "K" alloy Monel nozzle.

The British Oxygen Co., Ltd.

One section of this stand is devoted to plant and materials for metal-spraying; another section is allocated to oxygen-cutting machines; and there is the main section of welding and cutting plants.

The visitor will have the opportunity of inspecting and having demonstrated the following items from the B.O.C. range:—"Alda" portable high-pressure oxy-acetylene welding outfits, Models A, B, and O. All sections of metals can be welded with these equipments: A being designed for thicknesses up to $\frac{1}{8}$ in., B, thicknesses up to 1 in., and O for work on light steel and for burning lead.

Oxy-acetylene equipment for cutting iron and steel includes the familiar H, MS, and C types of B.O.C. hand-cutters. This year, in addition to the now well-known L-type cutter, visitors will have the chance of seeing tried out the new light pattern cutter, type No. 9. This has been specially designed for sheet steel up to $\frac{3}{16}$ in. thick.

For service with the welding blowpipes and cutters mentioned, the company manufacture a range of gas-pressure regulators, the principal types of which may be seen on the stand.

The company will have a representative range of welding rods and fluxes on their stand. In view of the ever-increasing use of metals and the introduction of new alloys, particularly of the non-ferrous category, a special feature is to be made of giving advice upon the correct materials and technique to use for each material upon the jointing of which help is sought.

The British Gas Federation—Industrial Exhibit.

This exhibit shows some striking examples of the use of gas in industry. The most spectacular exhibit will be a Greenwood and Batley $1\frac{1}{2}$-in. horizontal forging machine, shown in conjunction with a gas-fired forge furnace. Next to this is a small mattress belt conveyer oven furnace, with natural draught gas burners, made by the Incandescent Heat Co., Ltd.

In the working heat-treatment shop visitors can have their own specimens heat-treated while they wait. The equipment consists of an Incandescent Heat 3 ft. × 2 ft. × 1 ft. "Super" natural draught oven furnace, of the type

now so popular in aeroplane and motor-car works and wherever batch furnaces are required for hardening, carburising, reheating, or normalising.

Particular interest attaches to the "Sheffield" process for hardening high-speed steel tools in a special protective atmosphere derived from a mixture of burnt and unburnt town gas, with most of the water vapour condensed out.

A natural-draught salt-bath furnace can be made to heat up quickly and yet retain the advantages of simplicity and the even heating which is so essential if pots are to last well.

Recirculated atmosphere furnaces are used in aeroplane and motor-car works throughout the country for heat-treating many of the new light alloys, which have to be treated very accurately to give them the required characteristics. One of these furnaces is shown.

A great deal of fuel is used for melting non-ferrous metal. A new soft metal melting pot with a remarkably high efficiency will attract much attention, especially from members of the printing trade. In practice, this furnace in the larger sizes gives an overall working thermal efficiency of over 70%. The immersion burner system, which is made under licence from America, is known as the Holmes-Kemp system in this country, and makes use of completely premixed gas and air supplied by a blower to burners in mild steel tubes shaped like an inverted P and immersed in the metal to be melted.

For higher temperature metal-melting (brasses, etc.) a more conventional tilting crucible gas furnace made by the Morgan Crucible Co., is shown.

A recirculated atmosphere enamelling oven by F. J Ballard and Co. is a small representative of the very large gas-fired conveyer ovens in which this firm specialises.

In addition to the more conventional Potterton and Cochran gas water-heaters for central heating, there are medium temperature radiant panels by Bratt Colbran, Ltd., high-temperature radiant panels by Radiant Heating, Ltd., a unit air heater by Keith Blackman, Ltd., and an indirect gas air-heater by Ascot Gas Water Heaters, Ltd. Briggs Boilers, Ltd., show a completely automatic gas steam boiler.

An interesting exhibit of burners by Radiant Heating Ltd., includes Cox combustors and Duoflam burners. Precision burners are shown by Amal, Ltd., and by Chance Bros., while the Selas Gas and Engineering Co., Ltd., display laboratory muffle furnaces, injectors, and other specialities. A. H. Wilkes and Co., Ltd., are showing soldering-iron stoves and blow-pipes.

A notable feature of the exhibits is the amount of automatic control gear fitted, and many of the exhibits are controlling the furnaces which are working.

Blowers for the supply of air for air-blast burners have been provided by Keith Blackman, Ltd., who are also responsible for the compressors supplying gas and air to the glass-blowing burners.

Murex Welding Processes

A special display of electrodes, and an exhibit drawing attention to the use of heavy currents, and large gauge electrodes for fabrication of mild steel articles, and a model of a welding manipulator, will be shown.

The Murex "Cresta" electrode is of the universal type, has high mechanical properties, good rate of deposition, extremely easy slag removal, neat appearance, correct weld contours, is adaptable for hot-forging operations, and is suitable for D.C. and A.C. operation over a wide range of generator characteristics.

The "Ironex" electrode has been developed to provide faster, easier, and more efficient welding. It is of the extruded type, and the patented coating embodies a highly efficient principle of protection for the arc stream against atmospheric attack. Certain constituents in the coating readily combine with the atmosphere surrounding the arc, the products of this combination for the most part volatilise, and the remainder are dissolved in a readily removable slag produced by the fluxing constituents of the coating.

Another Murex product, the "Overhead" or vertical electrode, is suitable for the fabrication of mild steel structures in overhead and vertical positions. A structural exhibit consists of a welded stanchion base and wind connection constructed by Dorman, Long and Co., Ltd. A welded base is used instead of a riveted type, the gusset plates are placed across the flanges of the joist instead of in the plane of the flange faces, enabling eight welds to be used instead of four.

A second structural exhibit is one of six four-legged main stanchions supporting the 500-ft. roof girders of the new all-welded factory now under construction for the exhibitors. This has been designed for a vertical load of 225 tons plus lateral forces due to wind and temperature.

The "Belfinish" electrode has been marketed for several years and produces neat fillet welds of concave contour and with ample strength. The electrode is capable of depositing the exact amount of metal required per unit length, such as in small single-run fillets up to ¼-in. leg.

Other interesting electrodes are those for welding non-ferrous and stainless alloys, Monel metal electrodes, the new "Nicrex" (which is designed for depositing weld metal with high resistance to corrosion and high-temperature oxidation), and examples of welded material in each case.

Exhibits include a range of welding plant, both D.C. and A.C., a high-amperage set (500 amps. transformer), petrol and Diesel engine driven plant, welding glass and accessories.

The British Aluminium Co., Ltd.

Aluminium and its light alloys are shown in ingot and semi-manufactured forms.

Upon a turntable, surmounted by an aluminium sphere which is itself an example of clever spinning, are aluminium ingots, notched bars, sheets, strip in coil, circles, tubes, bars, and rods, together with a selection of the drawn and extruded sections for which the company has over 3,500 tools. Complicated hollow sections in pure aluminium are shown, in addition to sections of B.A. Co. standard alloys coated with pure aluminium.

Anodised and coloured aluminium tubes form the central feature of the turntable, and a separate display is made of aluminium work carrying this very popular protective finish.

Other aluminium exhibits include the following items:—Free-cutting aluminium alloy BA 35, which gives clean surfaces and screw-threads without clogging, on fully automatic machines. A marine floodlight and other exhibits of the new "Brytal" non-tarnishable reflectors, with an 85% reflectivity. Pistons of various sizes, including a large marine piston. Binnacle, wind-scoops, and other marine fittings. High-strength aluminium alloy forgings. Sundry pressure and gravity die-castings. Steel-cored aluminium conductors as used on the British National Transmission System. Textile reels and bobbins. Aluminium foil for heat and sound insulation.

An exhibit of quite special interest is a complete motor-cycle of somewhat advanced design, which serves to emphasise the possibilities of aluminium alloys, not alone for the engine castings, for which they are standard practice, but also (using, of course, alloys of high-tensile strength) for framework of motor-cycles. In the present instance, the complete framework is in Duralumin, and the fork links and various other parts are in aluminium-bronze.

Aluminium in major details of the stand—for example, showcase framing, fascia decoration and lettering (the latter in the company's virgin aluminium notched bars, bent cold), mouldings, and platform edging, together with the framing of works' photographs on an adjoining partition, complete a very representative display of the possibilities of the metal.

The Ether Edgewise Pyrometer.

Ether, Ltd.

A full range of pyrometers for recording, indicating, and controlling temperatures will be shown. The "Indicorder" recording pyrometer gives a continuous record of the temperature for one month without chart removal, at a speed of 1 in. per hour; it is also made to control the temperature of gas-, oil-, and electric-furnaces, in conjunction with a series of electrically operated gas- and oil-valves.

The Edgewise indicators are shown in various types and sizes, and cover temperature ranges up to 1,600° C. The Ether molten metal pyrometer for the measurement of molten ferrous and non-ferrous metal temperatures will also be shown. This instrument has a telescopic couple-holder to ensure economy in couple upkeep. All instruments have Stevenson's patent concentric movement, automatic cold junction compensators for variation in air temperature, high-resistance movements and thermocouples embodying mechanical and electrical interchangeability.

A range of instruments for normalising and heat-treatment of aluminium alloys for Air Ministry requirements is also shown.

The Workington Iron and Steel Co.

Their display will be on somewhat different lines from those at previous exhibitions. A small cinema, complete with ample and comfortable seating, has been built on the stand, and films will be shown of the manufacture of machine-cast pig iron at the Workington Co.'s works, and the mining of hæmatite ore at the Beckermet (Cumberland) Mines. The films are of a very detailed character, and may be said to be "pictorial visits" to the works and mines.

The actual materials shown will include samples of machine-cast pig iron and U.C.O. iron. Some applications of this latter quality will also be displayed.

Another section of the stand will be given over to a display showing the raw materials used in the production of pig irons.

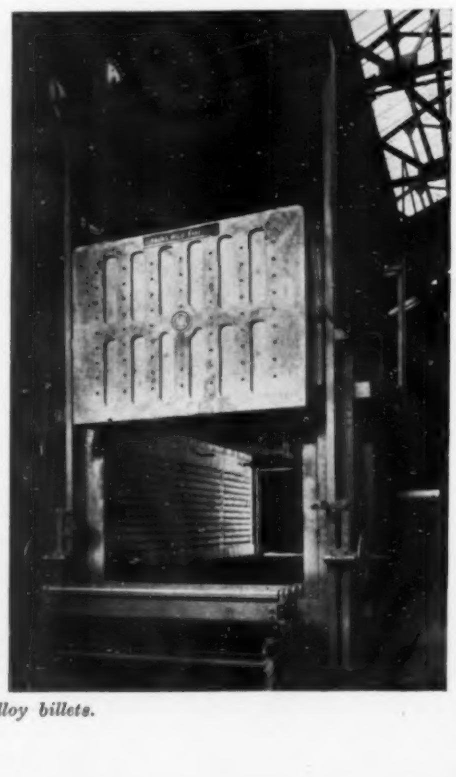
Electric Annealing Furnace for Aluminium Alloy Billets

A NEW furnace, of the roller-hearth type and double-ended, by Gibbons Wild Barfield is the fourth and largest furnace of its type now working in the factory where it has been installed and two more are in course of manufacture. It is used for annealing aluminium alloy billets, previous to forging, and also for the heat-treatment of certain components for aircraft use.

It is suitable for normal operating temperatures up to 600° C. and arranged for 440 volt, 50 cycle, 3 phase supply with reduction of element voltage by suitable transformers. The connected load is 192 kilowatts, there being three equal zones of 64 kW., and each zone is controlled separately by means of a millivoltmeter pattern indicating automatic temperature controller. There are three indicating pyrometers mounted on the side of the furnace and an arrangement of pilot lamps which show when the temperature is "high," "normal" or "low."

The elements are of 80/20 nickel chromium, wound in coils and supported by specially moulded refractories in the roof, hearth and side walls. The heating chamber is 16 ft. long, 7 ft. wide and 5 ft. high. The billets are carried through the furnace on heat-resisting steel rollers mounted on external bearings fixed along each side of the casing. These rollers are provided with chain sprockets at each end and are driven by roller chain from electric motor with reduction gearing.

For heat-treatment purposes the furnace is provided with two patent centrifugal fans, accelerating heating up and ensuring an even distribution of heat over the charge.



Large electric furnace for annealing aluminium alloy billets.

Metallurgy and the Aero Engine

By D. R. PYE, C.B., M.A., D.Sc., F.R.S.

The remarkable increase during recent years in the power of aero engines has been largely due to improvements in the quality of fuel available, but it could not have been achieved without many parallel improvements of a metallurgical character and it was to these latter improvements that Dr. Pye directed attention in the Autumn Lecture delivered at the recent meeting of the Institute of Metals, an abridgement of which is given in this article.

A COMPARISON of two aero engines, roughly of the same type and cylinder capacity, one designed this year and the other about six years earlier, reveals the outstanding fact that in six years the maximum power output, expressed as horse-power per cubic foot of cylinder capacity, has increased by amounts which vary in different designs between 50 and 100%. The problems introduced by this increase of power may be classified broadly as thermal and mechanical. On the thermal side the problem can be stated in general terms by saying that an internal combustion engine draws into its cylinder per minute, a certain weight of combustible mixture which depends upon the product of the engine speed and the density of the air supplied. Combustion of the mixture then generates an amount of heat per minute in direct proportion to its weight, and of this total heat generated a certain fraction is converted into mechanical work at the crankshaft.

The possibility of increasing this fraction of the total heat generated is strictly limited. It is fundamentally impossible to increase it very greatly, and as between the engines of to-day and of six or seven years' ago the increase has in fact not been more than about 10%. The important conclusion from this fact is that an increase of power of 100% is inevitably accompanied by an increase, in nearly the same ratio, of the *waste* heat, which must be got rid of with the exhaust gases and by conduction through the various metal components of the cylinder.

The greater part of this increase of waste heat goes out with the exhaust gases; but for 100% increase of total heat generated per minute there is at least a 40% increase of that communicated to the cylinder walls and other components, to be got rid of by conduction. Moreover, that conduction has to be effected without allowing rises of temperature in the various components which will prejudice their mechanical working one with another, for example, the pistons with the cylinder walls, and the valves in their guides.

The material employed for cylinder heads of air-cooled engines has not changed much in recent years, and development has been rather towards improving the forging and machining qualities. The light alloys have good conductivity compared with steel in any case, and as compared with the thermal problems inherent in pistons, valves, valve seats, and sparking plugs, those of the cylinder head itself are less acute. As regards steel for the cylinder barrel, the essential requirements are good machining qualities combined with the possibility of special treatment of the working surface.

Of all the many components in which a weakness may cause breakdown of an engine, there are two which remain, perhaps, the major preoccupation of the designer: the piston, and the crankshaft and its bearings; the problems of the piston being chiefly thermal, and of the crankshaft, mechanical.

In the face of the 100% increase of power for the same size of cylinder, the piston cannot avoid receiving as much as 40% more heat per minute over its top surface, and all the heat it receives must be dissipated either to the cylinder walls across an oil film, or from the under-side to the air and oil in the crank-case. Cooling from the under-side of the piston is comparatively small, and the only possibility of avoiding a big rise of temperature in the material is to have a higher thermal conductivity in the material, or to increase the thickness of the piston crown, so that the heat is rapidly transferred to the periphery without large differences of temperature along the radius.

The change from a cast iron to an aluminium alloy piston, under the same full throttle conditions, caused a fall of the maximum temperature in a 4-in. diameter piston from about 450° to 250° C., owing to the better heat conductivity and the greater thickness allowable of the light metal. It is typical, however, that these figures can only be given as rough approximations, because of the virtual impossibility of direct observation under real working conditions.

In the last five years the ability of piston materials to maintain the necessary strength at high temperature has undoubtedly improved, although reliable figures would be difficult to obtain. Nevertheless, for the sake of the necessary strength, and also to allow of an adequate rate of heat flow to the periphery, it has been necessary to thicken the piston crown and put up with a heavier piston, but any new material of specific gravity not greater than 3·0—the lower the better—and of thermal conductivity not inferior to Y alloy, which at the same time is able to maintain its mechanical properties better than Y alloy at temperatures of 300° C. and over, will be of major importance to the aero engine of the future.

The 100% increase in the waste heat from the cylinder has profoundly affected the design and metallurgy of the exhaust valve in the last five years. It would surely be difficult to find anywhere so many thermal, chemical, and metallurgical problems concentrated in so small a space. The difficulty of direct observation is not so great with the valve as with the piston, but the problem is far more complex. The successful development of the poppet valve and the seat on to which it closes calls for the most expert observation, and a critical analysis of the facts based upon wide knowledge of materials and engine design. In addition to mechanical and thermal possibilities, there is the chemical aspect introduced by the presence of tetraethyl lead in the fuel.

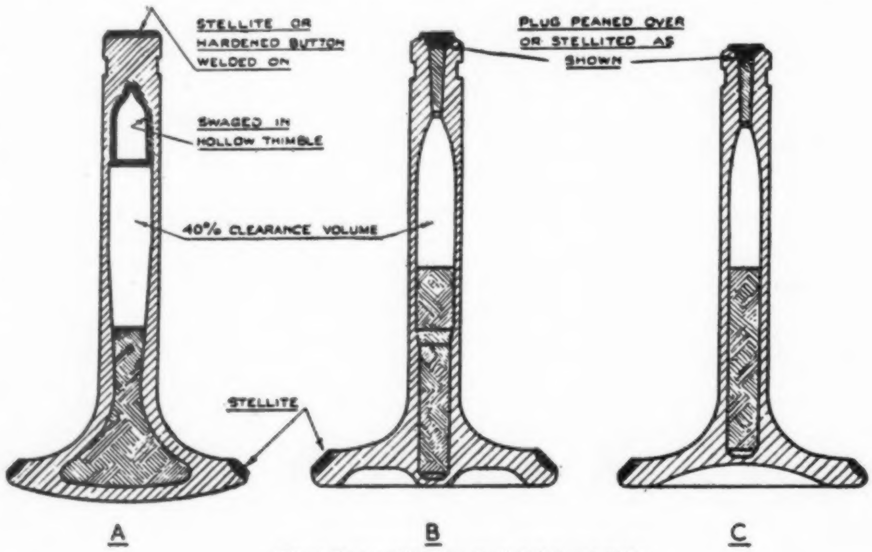
All the fuels demanded to-day by engines of the highest output owe their quality in some degree to the presence of the well-known "ethyl fluid." This is a mixture of tetraethyl lead with ethylene di-bromide and other substances, and it introduces a whole series of problems for the exhaust valve. It decomposes during the combustion in the cylinder with the formation of lead oxide and lead bromide, and the former of these, at the temperature of the exhaust gas, has disastrous effects upon the steel of the valves. These are effects which are not serious in the automobile engine.

The effects of the lead compounds on the exhaust valve are very much dependent on the valve temperature, and hence on engine output, and only become very serious when the valve is working under conditions far more severe than are ever met with in the automobile engine. Engine conditions, indeed, are extraordinarily critical. It has been found that a cylinder which will survive a hundred

hours' running quite happily when developing a brake mean effective pressure of 180 lb. per sq. in., will consistently fail through exhaust valve trouble when the power is increased by 10%.

The most popular valve steel in use to-day is one containing 12 to 14% each of nickel and chromium, but in spite of a high innate resistance to corrosion attack it is not able, by itself, to withstand oxidation in the presence of lead oxide at high temperatures. To get over this, advance has been along two lines: first, a complete re-design of the valve to maintain better cooling; and secondly, the covering of the seating ring, and now even the whole head of the valve, by stellite, a very hard alloy composed of cobalt, chromium, and tungsten, with about 2½% of carbon which has a better resistance to the effect of the lead.

The problem of cooling the valve is, like that in the piston, one of transferring the heat from the point where it is received—the head—to some point where it can be got rid of—ultimately, of course, to the surrounding air, but immediately to the metal of the cylinder body. With the mushroom valve there is little hope of getting rid of the heat directly from the head, and the problem is that of transporting it to the cooler stem, and thence across the working surface between the stem and the valve guide.



Three Types of Sodium-Cooled Exhaust Valve.

In the last five years the introduction of the chemical problem has forced designers to means for getting better cooling, and to face the complication and expense of the hollow valve, containing metallic sodium as its heat carrier which is now becoming universal in high-duty engines. In the accompanying illustration are shown cross-sections of three slightly varying types of "liquid-cooled" exhaust valve. The sodium is solid when cold, but melts at about the temperature of boiling water.

Even this complex design, however, combined with the stellite surface treatment, has not sufficed to cure the troubles of the exhaust valve. There is evidence of a rapid increase in the rate of attack even on stellite, in the presence of lead oxide, between 600° and 700° C. and again above about 900° C. The practice of covering the whole top surface of the valve, moreover, to prevent scaling, has led to trouble owing to a difference between the co-efficients of expansion of the steel and the stellite which has been found to cause cracking of the stellite over the head surface, so that the covering has completely disintegrated after 50 or 100 hours of high-duty running. A new material composed of about 80% nickel and 20% chromium has recently been tried for the same purpose and appears not to suffer in the same way when spread over the valve head. A possible further development is the fabrication of the entire solid parts of the valve from this non-ferrous alloy, thus avoiding the difficult welding processes involved in the composite valve. Finally, although the liquid sodium filling suffices to convey heat more rapidly from the valve head to the stem, it still remains to get this heat across the rubbing surface between the stem and the valve guide.

In those problems that are mechanical rather than thermal, the temperatures at which things work are at all times a vital factor. At this point, it is of interest to note that the mechanical problem of maintaining two surfaces rubbing without seizure occurs in a variety of forms in the internal combustion engine. There is the crankshaft in its bearings, in the first place, and the piston in the cylinder; but equally important and interesting to the metallurgist is the problem of wear between the valve stems and their guides, and of the camshaft and other parts of the valve gear. In each of these directions the last five years have brought changes in the material and the techique used in the preparation of the working surfaces, always in the direction of providing greater hardness to resist wear and "pick-up" under heavy loads. In both liquid- and air-cooled engines we find, for the cylinder surfaces, either a change to special steels capable of extreme hardening or to chromium-plated surfaces. Similarly, the so-called lead-bronze has almost entirely replaced white metal as the bearing material, and this in its turn has involved the use of a hardened steel shaft to prevent excessive wear.

The problem of wear, seizure, and "pick-up" between metal surfaces obviously cannot be considered apart from the question of lubrication, which under ideal conditions may preclude metallic contact entirely. Indeed, turning to the other end of the scale, it may be said that every surface, unless it has been chemically cleaned with the greatest care, is lubricated in some degree.

Our ability to preserve metal surfaces rubbing without seizure, in spite of heavier loading and rising temperatures, is vital to progress with the high-duty internal combustion engine.

So long as a complete unbroken oil film is maintained, the question of the proper "pairing" of metals does not arise, but even in a well-lubricated bearing there are the humps and hollows of the surfaces and whenever two humps pass one another so that they are helping to carry the load on the bearing, then the oil is squeezed away until there is no more than a single layer or so of oil molecules between the surfaces; very high temperatures are produced, and intermittent failure of the oil film and metallic cohesions will occur. So long as this state persists, the two surfaces are said to be in the state of "boundary lubrication."

It is easy to understand why high temperatures of the metal surfaces make the danger of seizure more acute. In the first place the rate at which the oil is squeezed away from between the surface humps as they approach will depend on its viscosity. As temperatures rise the viscosity falls, the thick film of oil is more quickly dispersed and the dangerous condition of boundary lubrication is earlier established. Besides this, however, there is the effect of a higher temperature on the danger of metallic cohesion when the oil film breaks down. At a higher temperature

all chemical activity is enhanced and there is, therefore, *prima facie*, likely to be a direct effect of temperature in the direction of promoting metallic cohesion and seizure.

Accepting that between two heavily loaded surfaces in contact a condition of boundary lubrication, though intermittent, is constantly recurring and that however good the oil, opportunities for metallic cohesion will occur, it is of great interest to consider what it may be possible to do to the metallic surfaces themselves to obtain relief and reduce the danger of seizure.

Beilby, after a careful microscopic study 35 years ago, of the process of polishing, suggested that this did not consist simply of a rubbing away of asperities to smaller and smaller dimensions, but that the act of polishing produced a fundamental change in the character of the surface either of a metal or non-metallic crystal, during which the crystalline character is lost and the molecules become arranged "all higgledy-piggledy" in the way characteristic of a liquid surface. The correctness of Beilby's conclusion and the frequent occurence of this amorphous layer, now known as the "Beilby layer" on a polished metal, is generally accepted. It has received remarkable confirmation from the work of Bowden, and more recently from that of Finch and others with the electron camera.

It is, of course, common knowledge to the engineer that he must not allow an engine to give its full power until the "running-in" process is complete, or scoring and seizure between the piston and cylinder will infallibly occur. This conforms with the physicists' observations upon the Beilby layer, that metal in this amorphous condition is in general harder and tougher than the crystalline variety. Moreover, what is probably more important, so long as the surface is crystalline one must expect its ultimate nature to be, as it were, a forest of minute crystalline peaks, rather than of the nature of a liquid at rest on which the surface irregularities are of molecular dimensions. It is fairly obvious that a metal surface of this latter type will be much more easily protected by an exceedingly thin oil film than a surface on which there are crystalline peaks, each hundreds of thousands of atoms high, which will pierce the oil film and make metallic contact, with local high temperatures and an immediate danger, or even certainty, of some metallic cohesion.

Finch has suggested that if a suitably oxidised magnesium-aluminium alloy surface is used, it is possible by polishing this "to form spinel with a permanently amorphous and therefore smooth Beilby layer." The usual aluminium alloys used for pistons, on the other hand, become spontaneously covered with a thin layer of very hard aluminium oxide. This oxide layer is, or can be made, amorphous ; but Finch's observations gave evidence that during the process of running-in, the oxide layer, instead of settling down into a smooth amorphous bearing surface, became converted into a layer of minute sapphire crystals. It has long been known that the wear of the cylinder barrel is more severe with an aluminium than with a cast-iron piston, in spite of the greater softness of the former. It has hitherto been supposed this was due to the embedding of abrasive particles in the soft aluminium piston, but the explanation of Finch that aluminium forms its own peculiar kind of grinding surface with sapphire teeth, is not only more picturesque, but probably more true also.

Cast iron is an example of a material long known to be in the first rank as a bearing material, and here recent research has shown conclusively that it owes its quality to a unique faculty for preparing its own bearing surface. Cast iron contains minute particles of free carbon in the form of graphite. The methods of X-ray and electron diffraction have shown that the carbon atoms in graphite are built up together in the form of thin flat plates or flakes, and that when a smooth surface of cast iron is polished this has the effect of bringing out the occluded graphite flakes and of spreading them out over the iron surface so that their slip planes are parallel to it. In this way they act as a lubricating layer protecting the iron from abrasion. It is this unique power of forming a good bearing surface which keeps cast iron supreme as a piston ring material in spite of it being entirely unsuitable from almost every other point of view. It has poor elastic properties, it is brittle, and it conducts heat badly, but the essential thing is that a piston ring *must* continue to rub without seizure under conditions in which satisfactory lubrication is impossible, and therefore we put up with the shortcomings of cast iron because of its peculiar virtue in this one respect.

A piston ring may seem an insignificant trifle in the whole design, but it is, perhaps, the most critical element in the piston. It is probable that more money has been spent in bringing the modern piston ring to its present imperfect stage of development than on any other single element of the design, and the problem is still one in which there is great scope for the metallurgical physicist. The reason why piston ring development is so expensive is that nothing short of prolonged tests at nearly full load in the actual engine will search out its weakness, and the failure, if it comes, may be the starting point of widespread damage.

I have said enough now to show you that engine development is almost synonymous with development of the material the engine is made of ; an improved fuel may allow a higher supercharge, but full use cannot be made of it without parallel improvements in a hundred other directions to meet the more severe conditions of heat flow and mechanical loading. The new problems range from the call for a 150 ton steel to the need for a more stable lubricating oil or an improved insulator for the sparking plug ; but undoubtedly it is the metallurgist who must chiefly and always be at hand to advise, and he in his turn must be ready to listen to what the pure physicist can tell him.

Emphasis has been given to the importance of a knowledge of surface conditions and the ultimate structure of metal surfaces in terms of atomic arrangement. Hitherto we have been able to rely safely upon an oil film to keep down the extent of the metallic contacts ; but as the temperatures of the working surfaces increase the viscosity of the oil gives less and less protection, and the nature of the metal surfaces will play a more and more important role in the avoidance of seizure.

The line taken by the engineer to-day is to make use of one of the recognised methods, of which there are several, of producing a hardened surface ; but do we know accurately, in terms of the ultimate atomic structure, *why* one surface is hard and another soft ? If the physicist would tell us that, we might make a big step towards the goal of the perfect piston ring and the unseizable bearing surface. And there are plenty of other problems about which we engineers will continue to grope, if we do not get the physicist to teach us the ultimate nature of the materials with which we work.

Modern Industrial Furnaces

The current issue of "Modern Industrial Furnaces," published by Messrs. Stein and Atkinson Ltd., 47, Victoria Street, London, S.W. 1, contains many furnace installations dealing with larger output, lower costs and stricter heat control than in those described in the previous issue ; a rather long interval having elapsed since the preceding issue was published. The contents include : producer-gas-fired recuperative bogie furnaces for annealing large forgings and large plates, soaking pits, strip mill for continuous reheating of steel billets and steel slabs ; coke-oven gas-fired furnaces for heat-treatment of forgings ; oil-fired rotating hearth continuous furnace for heat-treatment of tools ; equipment for softening stainless steel strip, annealing stainless steel sheets, annealing steel tubes and cast-iron pipes, mechanical stokers, annealing steel castings, melting alloy iron and bronze and aluminous cement ; furnace control gear, travelling, weighing and mixing car, and furnaces for melting zinc and glass.

A Continuous Hardness Test: Periodic Hardness Fluctuations

By EDWARD G. HERBERT, B.Sc., M.I.Mech.E.

A new hardness test has been developed which produces automatically a permanent record of hardness changes occurring in metals during ageing. The basis of the test is a scratch or groove formed in a slowly traversing specimen. The usual type of scratch test being unsuitable for exhibiting ageing changes, a new test is introduced in which a groove is rolled by a rotating ball. This test is shown to be susceptible to changes of hardness due to work-hardening and age-hardening, and the results are readily expressed in Brinell hardness. The continuous hardness test is used to investigate periodic fluctuations of hardness following magnetic and thermal disturbances. The periodic fluctuations are attributed to electro-magnetic pulsations in the atomic structure of the metal. The author presented this paper to the recent meeting of the British Association for the Advancement of Science.

THE purpose of a continuous hardness test is to exhibit the changes of hardness, and of physical properties associated with hardness, which may occur in metals with the lapse of time, generally known as ageing phenomena. Such a test should produce automatically a permanent record of the hardness at every instant during the ageing period. In particular, the continuous hardness test is intended to facilitate the further study of those periodic fluctuations of hardness which occur in metals whose structure has been recently subjected to drastic mechanical, thermal, or magnetic disturbance.

A study of periodic hardness fluctuations has been described by the author.[1, 2, 3] The method adopted was that of making tests with the "Pendulum" hardness tester at close intervals of time over as long a continuous period as was practicable, usually 10–14 hours. This process, though efficient, is laborious, and is subject to limitations, especially in the period covered, since the fluctuations in question may persist for several days and nights, or, indeed, for weeks. To pursue the study of these phenomena and to facilitate the study of age-hardening, which is such an important attribute of modern light alloys, it was desirable to produce a hardness test which should be automatic, continuous, and capable of producing a permanent record covering as many days or weeks as might be desired.

The apparatus which has now been developed is shown diagramatically in Fig. 1.

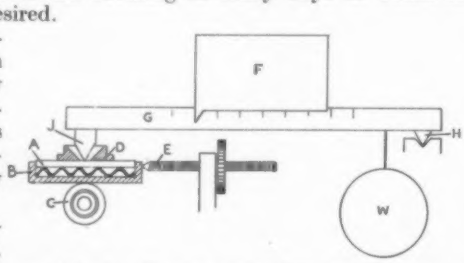


Fig. 1.—The continuous hardness tester.

The specimen A, $1\frac{3}{4}$ in. in length, is mounted in a carriage B, consisting of a shallow brass box containing a corrugated strip of lead and a mass of plasticene. The specimen, lapped flat and polished, is pressed into this matrix, which holds it firmly and is capable of withstanding pressure. The carriage containing the specimen is pressed upwards by the loaded ball-bearing C against the flat surface of a hard steel bush D, rigidly mounted in the apparatus. The carriage is suitably guided, and is moved longitudinally by the feed-screw E, rotated by clockwork, and making one revolution per hour. The pitch of the feed-screw is $\frac{1}{40}$ in., and the time occupied in traversing the specimen from end to end 66 hours. The time of traverse can be shortened or extended without limit by suitable gearing. A load W and a movable poise F are mounted on a beam G, graduated in kilograms and supported at one end on the long knife-edge H. A grooving tool J is attached to the beam, and passing through the hole in the bush D rests on the traversing specimen with a predetermined load. The effect is to produce in the specimen a scratch or groove whose dimensions (depth and width) measure the hardness of the specimen at each instant during the time of traverse. The groove is thus a permanent record of any hardness changes which may have occurred during that time.

In a recent development of the apparatus the traversing specimen and the grooving tool are immersed in a bath of oil, heated to a temperature of 200° C. or less, controlled by thermostat. The purpose is to study the effect of temperature on the periodicity and amplitude of the hardness fluctuations, and in particular to record the hardness changes which take place during the "artificial ageing" of light alloys.

The scratch test for hardness is well known. It has been investigated by Hankins,[4] who used a loaded diamond with an angular cutting edge.

Many continuous hardness testing experiments have been made with angular scratching tools, but these have given no satisfactory results. The action of the angular tool is that of a double ploughshare, displacing metal from the furrow and depositing it in a ridge on either side. This drastic deformation of the metal so changes its characteristics that the dimensions of the scratch may have little correspondence with the properties of the metal in its original undeformed state.

This has been confirmed by Tamman and Tampke,[5] who, using a gramophone needle under loads of 55–125 gr., found that the width of the scratch was unaffected by the degree of work-hardening previously applied to the specimen. They surmise that the scratching tool work-hardens the metal to its utmost capacity and measures the hardness thus artificially induced by the test itself. This is in contradistinction to the Brinell and other indentation hardness tests, which do indeed work-harden the metal, but only to a moderate degree, so that these tests are capable of giving an indication of the degree of work-hardening previously existing. Tamman and Tampke further proved that the scratch test as applied by them was incapable of showing any increase in the hardness of duralumin in the course of its age-hardening.

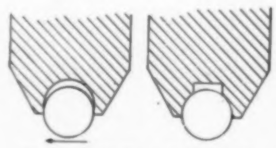


Fig. 2.—Ball and socket for rolled groove test.

As the scratch test with angular and pointed tools seemed incapable of giving any useful information about ageing changes, a new method of testing was developed.

The Rolled Groove Test.—In this method a steel ball, 1 mm. in diameter, is placed in a hard steel socket,

1 Proc. Roy Soc. A., vol. 120, p. 265.
2 METALLURGIA, 1931, vol. 4, pp. 9 and 47.
3 "Ageing of Tool Steel." Inst. Mech. Eng., 1933, vol. 124, p. 645.

4 Hankins. Inst. Mech. Eng., 1923, vol. 1, p. 423.
5 *Zeitschrift fur Metallkunde*, 1936, 28 (11), 336–7.

illustrated in Fig. 2. The ball rests in a highly polished spherical cavity, part of which is cut away to reduce friction. Under the combined vertical load and horizontal traversing force, the ball penetrates the surface of the specimen and rotating rolls a groove in it. The ball is slightly roughened by etching with nitric acid to give it a grip on the specimen and to obviate slip, while the etched

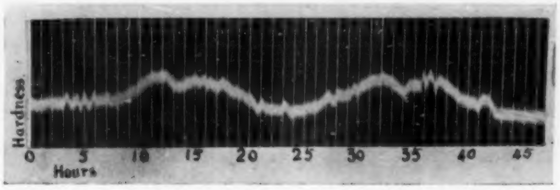


Fig. 3.—Autographic record of depth of groove in steel locally work-hardened.

ball forms a groove with a matt surface easily distinguished under the microscope. The rolling-ball test is in effect a continuous Brinell test, and the groove constitutes a permanent record of hardness changes occurring during its formation.

In view of the results of Tamman and Tampke and others, it was desirable to ascertain whether the new test is susceptible to changes of hardness due to work-hardening and age-hardening. Figs. 3 and 4 show two typical results, and serve also to illustrate the two methods used in recording results of the tests.

A specimen of mild-steel wire was work-hardened locally in two regions by pressing into it a steel cylinder placed at right-angles to the wire. Two cylindrical indentations were thus made in the specimen, which was then filed flat, the indentations being just eliminated, and polished. The specimen was mounted in the apparatus, Fig. 1, and a groove was formed in it with the 1 mm. ball under a load of 5 kilogs., and an autographic record was made of the depth of the groove.

Referring to Fig. 1, it will be understood that the plane of contact between the flat surface of the bush D and the flat surface of the specimen pressed against it, constitutes a plane of reference. The depth of the groove is the degree of penetration of the grooving tool below this plane of reference, and any variation in depth causes a corresponding movement of the load-bar G. By means of a tilting mirror, the image of a cross-wire is thrown on a revolving drum covered with photographic paper and driven by an electric clock. Thus movements of the load-bar corresponding to changes of depth and of hardness are autographically recorded. Magnification of 1,500 to 4,000

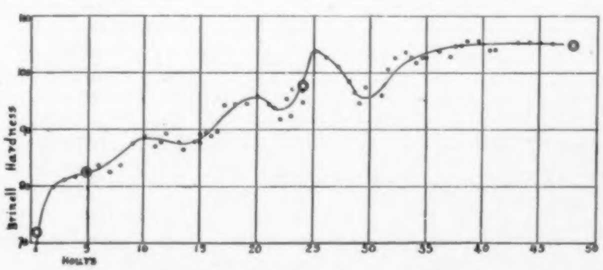


Fig. 4.—Age-hardening curve of duralumin by scanning rolled groove.

is used, and the apparatus is installed in a cabinet whose temperature is controlled by thermostat. The source of light is interrupted at intervals of quarter hour, so as to produce a time scale on the diagram. Fig. 3 is an autographic record of the depth of groove and of the hardness of the specimen of steel wire which had been locally work-hardened in two places as described. The record shows the increased hardness where the indentations had been made, and incidentally shows that the maximum hardness did not occur in the centre of the indentation where it was deepest. Thus the new test, unlike the scratch test, is susceptible to work-hardening effects.

Fig. 5.—Brinell impression and rolled groove, 1 mm. diamond 5 kilog. load. × 100.

Scanning the Groove.—In many cases, and particularly in that of hard steel, it is convenient to measure hardness by the width rather than the depth of the groove. A transparent scale graduated in hours is attached to the specimen alongside the groove, so that the hourly graduations can be read together with the corresponding width when the groove is projected at 100 magnification on the screen of a metallurgical microscope. In order to convert the width of the groove into Brinell hardness, the ball is allowed to rest on the stationary specimen for 30 secs. under the load of 5 kilogs., so as to form an indentation from whose diameter the Brinell hardness can be calculated. Three such Brinell impressions are made at the commencement of the test, and at the end, and at one or more intermediate positions during the test. A rolled groove and one Brinell impression under the same load (5 kilogs.) are shown in Fig. 5.

The ratio between the diameter of the Brinell impression and the width of the contiguous portion of the groove constitutes a conversion factor by means of which the width of the groove at any point can be converted to equivalent Brinell diameter and hardness. In scanning the groove, three width measurements are made at stages of one hour or less. The average width is converted into Brinell hardness and plotted on a time base. Fig. 4 is the result of scanning a groove rolled in duralumin after heating for 30 mins. at 520° C. and quenching. The test was made with 1 mm. ball and 5 kilogs. load. The large circles are the results of Brinell measurements made at ½ hour, 5, 24, and 48 hours after quenching. The small circles are Brinell hardness, calculated from the width of the rolled

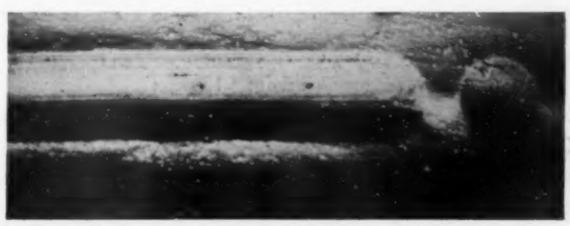


Fig. 6.—Brinell impression and groove in hard steel. 1 mm. diamond, 5 kilog. load. × 100.

groove multiplied by the factor 0·875 to convert to equivalent Brinell diameter. The scanning of the groove shows the characteristic fluctuating age-hardening of duralumin, and the four Brinell measurements lie on the curve. Thus, the new rolling test, unlike the scratch test, is susceptible to the age-hardening of duralumin.

Continuous Testing of Hard Steel.—The depth of groove produced in hard steel by a 1 mm. sphere under a load

of 5 kilogs., is of the order of 0.001 mm. To record autographically the variations in a dimension of this order would require a high magnification and undesirable elaboration. The width of the groove produced under these conditions is of the order of 0·1 mm., and the process of scanning such a groove projected at 100 magnification presents little difficulty. Continuous hardness tests in

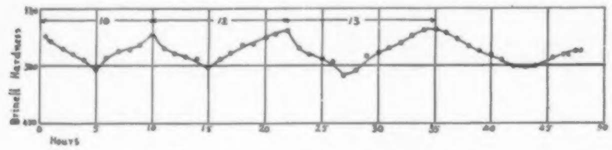


Fig. 7.—Periodic fluctuations in high-speed steel after secondary heat-treatment at 575° C. 1 mm. diamond. 5 kilog. load.

hard steel are made with a rigidly mounted diamond, having a hemispherical surface of 1 mm. diameter, under a load of 5 kilogs. This form of grooving tool has been used by O'Neill.[6] The rolling test has not been applied to hard steel, as no complete diamond sphere was available, The stationary diamond produces a well-defined groove. with little ridging. Fig. 6 shows a groove produced in hard steel by a 1 mm. diamond under 5 kilogs. load, and the corresponding Brinell impression made with the same diamond under this load. The conversion factor is 0·91

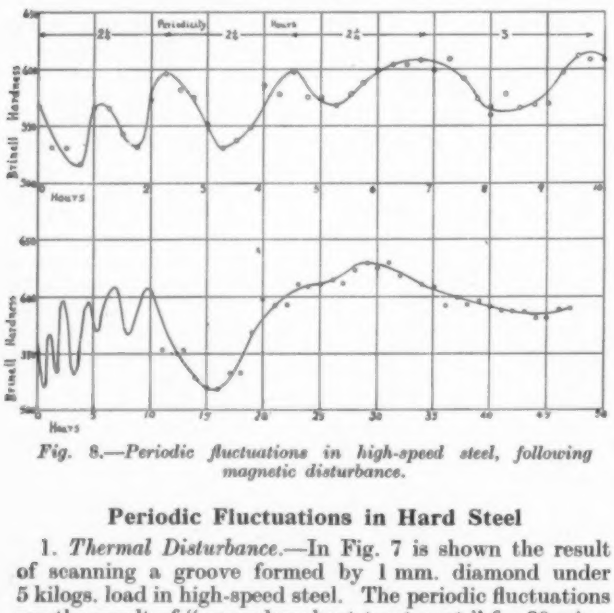


Fig. 8.—Periodic fluctuations in high-speed steel, following magnetic disturbance.

Periodic Fluctuations in Hard Steel

1. *Thermal Disturbance.*—In Fig. 7 is shown the result of scanning a groove formed by 1 mm. diamond under 5 kilogs. load in high-speed steel. The periodic fluctuations are the result of " secondary heat-treatment " for 30 mins. at 575° C., and quenching in water. Three width measurements of the groove were made at each hourly period during 48 hours immediately after quenching. The periodicity of the fluctuations increases from 10 hours to 16 hours per

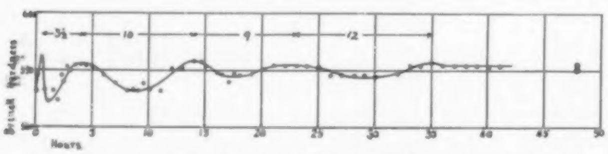


Fig. 9.—Periodic fluctuations in high-speed steel after demagnetisation.

cycle. This result is similar to those obtained in a previous research,[3] when it was shown that the fluctuations originate (at a more rapid rate) when the specimen is actually in the furnace undergoing heat-treatment. They slow down on cooling to atmospheric temperature, and thereafter tend to slow down further and to damp out.

Another instance of fluctuations caused by thermal treatment has been shown in Fig. 4. The general increase of hardness in the age-hardening of duralumin is attributed to the precipitation of certain constituents, but this can scarcely account for fluctuations of hardness, including temporary softening. It is believed that periodic fluctuations due to thermal disturbance are superimposed upon a steady rise of hardness, due to precipitation, the two independent processes resulting in the fluctuating rise.

2. *Magnetic Disturbance.*—Fig. 8 shows the fluctuations of hardness in high-speed steel following magnetic disturbance. The specimen was passed three times over a 3-mm. gap in an electro-magnet, the flux in the gap being 17,500 gauss. A groove was made with 1 mm. diamond under 5 kilogs. load during 48 hours after magnetic treatment. The upper curve shows on an extended time scale the result of scanning the first 10 hours at intervals of 15 mins., and the lower curve shows the complete test. The rather sudden increase of periodicity from $2\frac{1}{4}$ hours to 19 hours per cycle is unusual. A more gradual slowing down is generally met with.

3. *Alternating Field.*—Fig. 9 shows the fluctuations induced in high-speed steel by an alternating magnetic field. The specimen, previously magnetised and aged to stability, was placed for 3 mins. across the gap of a demagnetiser fed with alternating mains current at 230 volts, 50 periods. The resulting fluctuations, initially rapid, slowed down to a periodicity of 12 hours per cycle, and appeared to have damped out 40 hours after the disturbance which caused them.

Nature of the Fluctuations

A large number of cases of periodic hardness fluctuations have now been investigated, and all have general characteristics similar to those in Figs. 7, 8, and 9. They have been induced by thermal, magnetic, and mechanical disturbances of the metallic structure, and no matter which of these three methods of disturbance has originated them, they have the same general character, similar periodicity and amplitude, and they have this further attribute in common—they can be stabilised at either a maximum or a minimum phase by placing the specimen for a few minutes in a constant magnetic field. The view is therefore taken that the fluctuations are electro-magnetic, and as such they may be regarded as an extension at the low-frequency end of the long series of electro-magnetic pulsations of which heat, light, and wireless waves are the most familiar examples. They are most conveniently exhibited and studied as changes of hardness in metals, but hardness, though easily measured, is an indeterminate property, never completely defined. Hardness changes must be regarded in this connection as evidence of changes of an unknown but probably fundamental character in the atomic structure of matter.

Although the present work is confined to a study of hardness changes, there is accumulating evidence of periodic fluctuations of other physical properties of metals. Thus, R. W. Bailey shows[7] periodic fluctuations in steel, attributed to changes in the modulus of elasticity, which appear to have persisted for 500 hours with a periodicity of the order of 200 hours, and other instances of apparently periodic changes have been met with.

The principal aim of the researches now in progress is to establish definite relationship between various specific disturbances and the periodicity and amplitude of the resulting fluctuations. In this way, it is hoped to control the incidence of maxima and minima with a view to stabilising selected phases and rendering permanent some useful changes in the properties of metals. It is hoped that in the course of the research further light will be thrown on the intrinsic character of the phenomena. The new method of testing and recording hardness changes has already proved its value.

6 O'Neill. "Hardness of Metals and Its Measurement," p. 146.

7 R. W. Bailey. Inst. Mech. Eng., 1935, vol. 121, p. 146.

Foamed Blast-Furnace Slag

Foamed blast-furnace slag has been used in the building industry on the Continent for some years. Manufacture of the material has now begun in Britain, and this Report, by Dr. T. W. Parker, of the Building Research Station, deals chiefly with the results of an investigation on the suitability of this material as an aggregate.

THE Blast Furnace Committee of the Iron and Steel Industrial Research Council has had under consideration from time to time the question of blast-furnace slags, both with respect to the reactions inside the furnace and to the utilisation of the slags when made. In the past a number of British blast-furnace slags have not been marketable, largely because of their liability to disintegrate when air-cooled. Extensive research has been carried out on the subject and this report deals with that section of the work concerning foamed slag. Consideration is given to the possibility of stabilising slags by foaming, and the properties of the resulting material when used as a light-weight concrete aggregate. The results show that foamed slags of widely divergent composition have properties which make them eminently suitable as a concrete aggregate, and to that extent the work opens up possibilities of increasing the available market for slags.

The manufacture of foamed slag is the treatment of molten slag from blast-furnace pig-iron manufacture with a limited amount of water or other volatile liquid for gas. The slag is expanded into a spongy mass, and at the same time is fairly rapidly chilled. The suitability of foamed slag as an aggregate depends upon it satisfying certain requirements the determination of which was the object of the investigation described in this report, and particular attention was paid to verifying that slags which normally "fail" on slow air-cooling are stabilised by foaming.

A range of slag compositions was used, of which the majority of the individual samples had a high lime content, such as would cause falling if the slags were slowly cooled in the normal way. Experimental foaming tests were made on these, and observations made on the foamed products under a variety of weathering and storage conditions. Attempts were also made to accelerate any disintegrating effects by annealing and by water and steam treatments. No evidence of falling in these foamed slags was observed, and it is concluded that foaming stabilises falling slags, at least in the range of compositions examined (i.e., up to lime contents of 50%).

Attention was also paid to the question of whether the contents of sulphur compounds in the foamed slags were likely to be at all deleterious when the material is used in concrete. No free sulphur as such exists in blast-furnace slag, but a certain amount is always present chemically combined as sulphide or sulphate. The two objects of the tests were to determine whether steel reinforcement in concrete would be affected by the sulphide, and whether the cement would be attacked by the sulphate. In agreement with the results of other investigators, it is concluded that the foamed slag concrete is not intrinsically corrosive to the steel; on the other hand, the protection afforded to steel by lightweight concrete, whether made with foamed slag or other lightweight aggregate, is not so complete as that given by heavy aggregates. An examination was made to determine whether sufficient sulphate is present in foamed slags to produce an expansion by reaction with the cement in the presence of moisture. A test was devised to determine the "available sulphate," on the assumption that only the sulphate in the surface layers of the aggregate would be reactive to the cement. The permissible limit of available sulphate, by the suggested method, was assessed at 0·5%, this being based on the experience of the Building Research Station with other lightweight aggregates, and on long-period strength tests on foamed slag concrete. All but one of the samples had available sulphate contents below the permissible limit.

Tests were devised which are considered to be suitable for use in standard specifications for foamed slag.

It is concluded that the strength of the concrete varies in a general way with the weight per cubic foot. On the whole, the materials examined gave concretes showing higher strengths than concretes made with other lightweight aggregates, although the weights per cubic foot were higher than those of the lighter types of lightweight aggregate. Such properties as thermal insulation, moisture movement, ease of plastering, etc., were comparable with those of the lighter types.

Some Notable Sheffield Works

(*Continued from page 156.*)

a brief historical account of the developments of these steels, together with the various manufacturing operations, including melting in the high-frequency furnace, turning into ingots, the treatment of the ingots preparatory to reheating and rolling into plates, which are sheared and again heated for sheet rolling operations. The subsequent annealing of "Staybrite" sheets in a special type of gas-fired furnace was also shown, together with the trimming, sorting and inspection operations of the finished sheet. Examples of the mirror finish possible on this material proved of great interest, as also did the many applications, although the increasing use of this material is bound to have some effect on the use of non-ferrous metals with which some of the visitors were directly concerned. Production of sheets is organised on a semi-automatic plan which operates very efficiently.

About half-an-hour was devoted to a very hasty inspection of the Brown-Firth Research Laboratories and from the lecture theatre, where the film was shown, the various departments were visited, including those devoted to experimental steel-making, heat-treatment, pyrometry, high temperature mechanical testing, metallographic, microscopic, physical, mechanical testing, corrosion, high temperature oxidation, chemical analysis, inclusions and "gases," X-rays, and refractories laboratories.

The general expression of opinion indicated that the general cleanliness of these was in a great measure due to the control, both scientific and technical, and the excellent manner in which the work is organised to make full use of the modern equipment.

It should be mentioned that the specially resistant steels, the manufacturing operations of which were shown by the film, are the products of Firth-Vickers Stainless Steels Ltd., Staybrite Works, Sheffield.

Increased Production of Manganese in U.S.S.R.

ACCORDING to the draft figures of the Third Five-Year Plan for the Chiatury manganese industry, the output of manganese ore by the last year of the Third Five-Year Plan will be increased to 2½ million tons. (This year the output of Chiatury manganese is estimated at 1,650,000 tons.) Under the Third Five-Year Plan existing mines will be enlarged, and two new mines will be sunk. One of the latter (the Porokhnal-Shukrutsky) will be the largest ore mine in Chiatury; raising and haulage processes will all be mechanised. The Third Five-Year Plan also makes provision for the building of schools, parks of culture and rest, and other amenities for the Chiatury miners.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£100	0	0

ANTIMONY.

English		£93	0	0
Chinese		81	0	0
Crude		45	0	0

BRASS.

Solid Drawn Tubes	lb.	0	1	0¾
Brazed Tubes	,,	0	1	2¼
Rods Drawn	,,	0	0	11½
Wire	,,	0	0	9⅞
*Extruded Brass Bars	,,	0	0	6⅞

COPPER.

Standard Cash		£56	11	0
Electrolytic		62	5	0
Best Selected		62	1	0
Tough		61	11	0
Sheets		91	11	3
Wire Bars		63	6	0
Ingot Bars		63	6	0
Solid Drawn Tubes	lb.	0	1	2¼
Brazed Tubes	,,	0	1	2¼

FERRO ALLOYS.

‡Tungsten Metal Powder nominal	lb.	£0	9	1½
‡Ferro Tungsten .. nominal	,,	0	9	0
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL 2-4% Carbon, scale 12/- per unit	ton	34	15	0
4-6% Carbon, scale 8/- per unit	,,	24	5	0
6-8% Carbon, scale 7/6 per unit	,,	24	0	0
8-10% Carbon, scale 7/6 per unit	,,	24	0	0
¶Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 12/6 per unit	,,	37	0	0
Guar. max. 1% Carbon, scale 13/- per unit	,,	39	0	0
§Guar. max. 0.5% Carbon, scale 13/- per unit	,,	49	0	0
‡Manganese Metal 97-98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	5
§Ferro-Vanadium 25-50%	,,	0	12	8
§Spiegel, 18-20%	ton	9	15	0
Ferro Silicon—				
Basis 10%, scale 3/- per unit nominal	ton	10	5	0
20/30% basis 25%, scale 3/6 per unit	,,	14	10	0
45/50% basis 45%, scale 5/- per unit	,,	12	0	0
70/80% basis 75%, scale 7/- per unit	,,	17	0	0
90/95% basis 90%, scale 10/- per unit	,,	30	0	0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	15	15	0
§Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20-25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	5

FUELS.

Foundry Coke—				
S. Wales	—	2	2	6
Scotland	—	2	2	6
Durham	—	1	16	6
Furnace Coke—				
Scotland	—	2	0	0
S. Wales	—	1	17	6
Durham	—	1	15	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£85	0	0
*Commercial Ingots		66	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	1	1
*Cored Bars	,,	0	1	3

MANUFACTURED IRON.

Scotland—			
Crown Bars	£13	10	0
N.E. Coast—			
Rivets	12	15	0
Best Bars	15	15	0
Common Bars	12	10	0
Lancashire—			
Crown Bars	13	10	0
Hoops	14	2	6
Midlands—			
Crown Bars	13	10	0
Marked Bars	15	15	0
Unmarked Bars		—	
Nut and Bolt Bars	11	15	0
Gas Strip	14	2	6
S. Yorks.—			
Best Bars	15	15	0
Hoops	14	2	6

PHOSPHOR BRONZE.

*Bars, "Tank" brand, 1 in. dia. and upwards—Solid	lb.	£0	1	1
*Cored Bars	,,	0	1	3
†Strip	,,	0	1	1
†Sheet to 10 W.G.	,,	0	1	1½
†Wire	,,	0	1	3
†Rods	,,	0	1	3½
†Tubes	,,	0	1	6
†Castings	,,	0	1	3½

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—			
Hæmatite M/Nos.	£6	3	0
Foundry No. 1	5	15	6
,, No. 3	5	13	0
N.E. Coast—			
Hæmatite No. 1	6	3	0
Foundry No. 1	5	3	6
,, No. 3	5	1	0
,, No. 4	5	0	0
Silicon Iron		—	
Forge	5	0	0
Midlands—			
N. Staffs. Forge No. 4	5	3	0
,, Foundry No. 3	5	6	0
Northants—			
Foundry No. 1	5	6	6
Forge No. 4	5	0	6
Foundry No. 3	5	3	6
Derbyshire Forge	5	3	0
,, Foundry No. 1	5	9	0
,, Foundry No. 3	5	6	0
West Coast Hæmatite	6	3	0
East ,, ,,	6	3	0

SWEDISH CHARCOAL IRON AND STEEL.

Export pig-iron, maximum percentage of sulphur 0·015, of phosphorus 0·025.
Per English ton Kr.185

Billets, single welded, over 0·45 Carbon.
Per metric ton Kr.335-385
Per English ton .. £17 11 3/£20 3 9

Wire Rods, over 0·45 Carbon.
Per metric ton Kr.385-415
Per English ton .. £20 3 9/£21 15 0

Rolled Martin Iron, basis price.
Per metric ton Kr.335-355
Per English ton .. £17 11 3/£18 12 3

Rolled charcoal iron, finished bars, basis price.
Per metric ton......... Kr.360
Per English ton......... £18 17 6
f.o.b. Gothenburg.

SCRAP METAL.

Copper, Clean	£45	0	0
,, Braziery	41	0	0
,, Wire		—	
Brass	29	10	0
Gun Metal	44	0	0
Zinc	15	0	0
Aluminium Cuttings	72	0	0
Lead	18	10	0
Heavy Steel—			
S. Wales	3	10	0
Scotland	3	6	0
Cleveland	3	7	0
Cast Iron—			
Midlands	3	5	0
S. Wales	3	10	0
Cleveland	4	2	6
Steel Turnings—			
Cleveland	2	12	6
Midlands	2	5	0
Cast Iron Borings—			
Cleveland		—	
Scotland	2	2	6

SPELTER.

G.O.B. Official		—	
Hard	£19	0	0
English	24	0	0
India	19	15	0
Re-melted	19	15	0

STEEL.

Ship, Bridge, and Tank Plates.			
Scotland	£11	10	0
North-East Coast	11	10	0
Midlands	11	10	0
Boiler Plates (Land) Scotland	12	0	0
,, ,, (Marine) ,,		—	
,, ,, (Land), N.E.Coast	12	0	0
,, ,, (Marine) ,,		—	
Angles, Scotland	11	0	6
,, North-East Coast	11	0	6
,, Midlands	11	0	6
Joists	11	6	0
Heavy Rails	10	2	6
Fishplates	14	2	6
Light Rails	10	7	6
Sheffield—			
Siemens Acid Billets	11	15	0
Hard Basic .. £6 17 6 to	10	2	6
Medium Basic, £6 12 6 and	10	0	0
Soft Basic	8	15	0
Hoops	11	15	0
Manchester			
Hoops	11	5	0
Scotland, Sheets 24 B.G.	15	15	0

¶ HIGH-SPEED TOOL STEEL.

Finished Bars 14% Tungsten	lb.	£0	3	10
Finished Bars 18% Tungsten	,,	0	5	0
Extras :				
Round and Squares, ½ in. to ¼ in.	,,	0	0	3
Under ¼ in. to ⅛ in.	,,	0	1	0
Round and Squares, 3 in.	,,	0	0	4
Flats under 1 in. × ⅜ in.	,,	0	0	3
,, ,, ¼ in. × ⅛ in.	,,	0	1	0

TIN.

Standard Cash	£260	10	0
English	260	10	0
Australian		—	
Eastern	262	10	0
Tin Plates I.C. 20 × 14 box	1	5	6

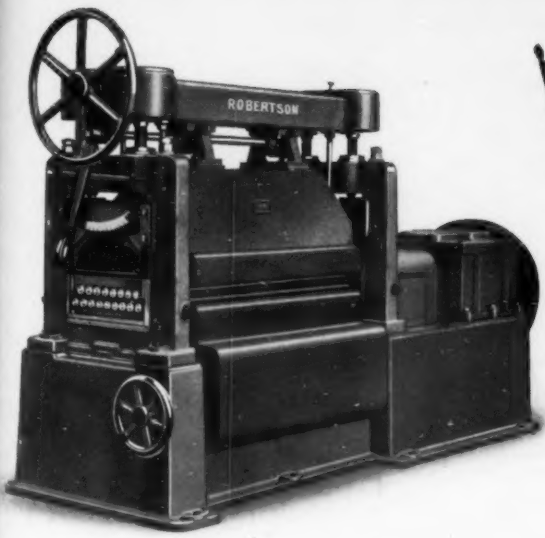
ZINC.

English Sheets	£36	10	0
Rods	30	19	0
Battery Plates		—	
Boiler Plates		—	

LEAD.

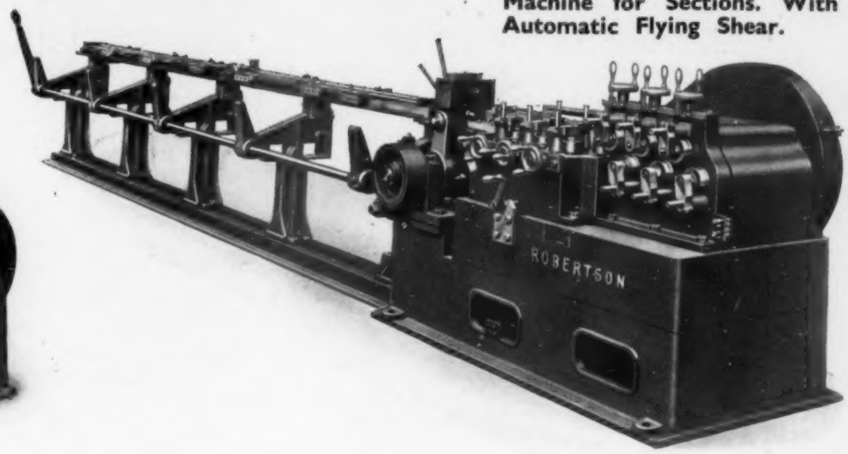
Soft Foreign	£22	6	3
English	24	10	0

* McKechnie Brothers, Ltd., Sept. 13. † C. Clifford & Son, Ltd., Sept. 13. ‡ Murex Limited, Sept. 13.
Subject to Market fluctuations. Buyers are advised to send inquiries for current prices when about to place order.
§ Prices ex warehouse, Sept. 13. ¶ The prices fluctuate with the price of Tungsten.

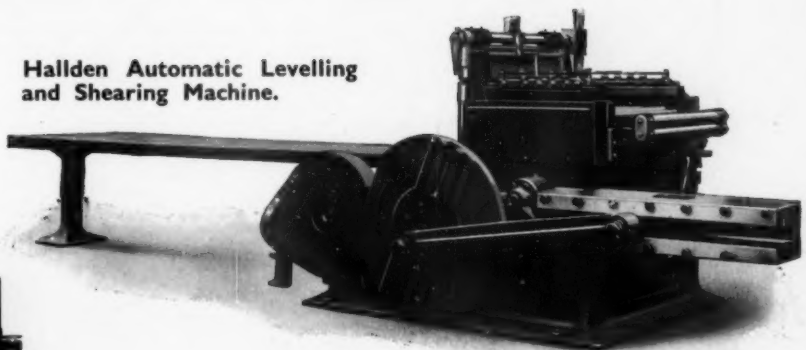


T. S. Type 17. Roll Sheet Leveller.

Straightening and Shearing Machine for Sections. With Automatic Flying Shear.

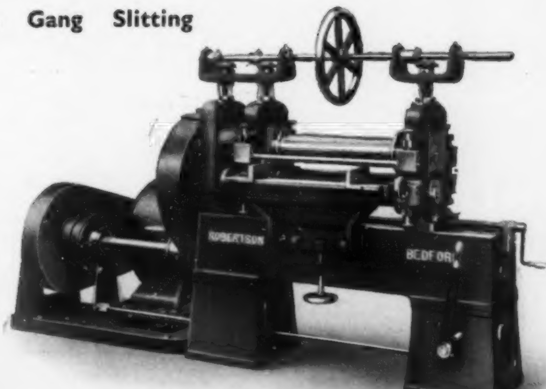


Hallden Automatic Levelling and Shearing Machine.

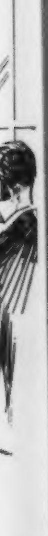


Multiple Die High-Speed Wire-Drawing Machine for Non-Ferrous Wire.

"G" Type Gang Slitting Machine.



20 in. x 40 in. HIGH SPEED TWO-HIGH STRIP ROLLING MILL with automatic coiling equipment, for Aluminium and light alloy strip and other non-ferrous metals.



METALLURGIA. *Contents.* For SEPTEMBER, 1937.

ADVERTISERS' ANALYSIS

Acids
Imperial Chemical Industries, Ltd., Imperial Chemical House, London, S.W. 1.

Aluminium
Aluminium Union, Ltd., Bush House, London, W.C.2.
British Aluminium Co., Ltd., King William St., London, E.C.4.
High Duty Alloys, Ltd., Trading Estate, Slough.
Wm. Mills, Ltd., Birmingham.
Northern Aluminium Co., Ltd., Bush House, London, W.C.2.
Rudge Littley Ltd., West Bromwich.

Anti-Friction Metals
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Brass and Bronze
Clifford, Chas. and Son, Ltd., Birmingham.
John Holroyd, Ltd., Rochdale.
Manganese Bronze & Brass Co. Ltd., Handford works, Ipswich.
McKechnie Bros., Ltd., Rotton Park St., Birmingham.

Burners
Nu-Way Heating Plants Ltd., Macdonald Street, Birmingham.

Casehardening Compounds
Amalgams Co., Ltd., Attercliffe Rd., Sheffield.
Fordath Engineering Co., Ltd., West Bromwich.
G.W.B. Electric Furnaces, Ltd., Belgrave House, Belgrave St., W.C.1.
Kasenit Ltd., Henry St., Bermondsey St., London, S.E. 1.

Castings (Iron)
Rudge Littley Ltd., West Bromwich.
Wallwork, H., and Co., Ltd., Roger St., Manchester.

Castings (Non-ferrous)
Magnesium Castings and Products, Ltd., Slough.
Manganese Bronze & Brass Co. Ltd., Handford Works, Ipswich.
William Mills, Limited, Grove Street, Birmingham.
Mond Nickel Co., Ltd., Thames House, Millbank, London, S.W. 1.
Northern Aluminium Co. Ltd., Bush House, Aldwych, London, W.C. 2.
Sterling Metals Ltd., Coventry.

Coke-Oven Plant
Gibbon Bros., Ltd., Albert Road, Middlesbrough.
Woodall Duckham, Vertical Retort & Oven Construction Co., (1920), Ltd.

Crucibles
Morgan Crucible Co. Ltd., Battersea Works, Church St., Battersea, London, S.W. 11.

Electrodes
British Acheson Electrodes, Ltd,, Sheffield.

Extruded Sections
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Northern Aluminium Co., Ltd., London.

Extruded Rods and Sections
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Northern Aluminium Co., Ltd., London.

Fluxes.
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham.
Imperial Chemical Industries Ltd., Dept. C.6, Imperial Chemical House, London, S.W. 1.

Forging Machines
Schiess Detries, A.- G., Düsseldorf.

Forgings
Northern Aluminium Co., Ltd., London.

Foundry Preparations.
Foundry Services Ltd., 285, Long Acre, Nechells, Birmingham.
Imperial Chemical Industries Ltd. Dept. C.6, Imperial Chemical House, London, S.W. 1,
J. W. Jackman & Co., Ltd., Vulcan Works, Blackfriars Road, Manchester.

Furnace Arches
Liptak Furnace Arches Ltd., 59, Palace Street, Victoria Street London, S.W. 1.

Furnaces (Electric)
Birmingham Electric Furnaces, Ltd., Erdington, Birmingham.
Demag Electrostahl, Germany.
Electric Furnace Co., Ltd., 17, Victoria St., London, S.W. 1.
General Electric Co., Ltd., Magnet House, Kingsway, W.C. 2.
G.W.B. Electric Furnaces, Ltd., Belgrave House, Belgrave St., London, W.C. 1.
Integra Co., Ltd., The, 183, Broad Street, Birmingham.
Kasenit Ltd., Henry St., Bermondsey St., London, S.E. 1.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham
Morgan Crucible Co. Ltd., Battersea Works, Church Street, Battersea, London, S.W. 11.
Siemens Schuckert, Ltd., New Bridge Street, London.
Wild-Barfield Electric Furnaces, Ltd., Elecfurn Works, North Road, London, N. 7.

Furnaces (Fuel)
British Furnaces Ltd., Chesterfield.
Burdon Furnace Co., 136, West Princes Street, Glasgow.
Cassel Cyanide Co. Ltd., Room 170F2, Imperial Chemical House, London S.W.1.

Continued on next page.

Furnaces (Fuel)
Dowson and Mason Gas Plant Co., Ltd., Levenshulme, Manchester.
Gibbons Brothers, Ltd., Dudley, Worcestershire.
Incandescent Heat Co., Cornwall Rd., Smethwick, Birmingham.
James Howden & Co. Ltd., 195, Scotland St., Glasgow, Scotland
Kasenit Ltd., Henry St., Bermondsey St., London, S.E. 1.
Ofag Ofenbau, Düsseldorf, Germany.
Priest Furnaces Ltd., Albert Road, Middlesbrough.
Fused Blocks
Imperial Chemical Industries Ltd. Dept. C.6, Imperial Chemical House, London, S.W. 1.
Gas
British Commercial Gas Association, Gas Industry House, 1, Grosvenor Place, London, S.W. 1.
Gears
Wallwork, Henry, and Co., Ltd., Red Bank, Manchester
Shorter Process Co., Ltd., Savile St. East, Sheffield
Gun Metal Ingots and Rods
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Hardening Metals
Shorter Process Co. Ltd., Savile St. East, Sheffield.
Ingots (Non-Ferrous)
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
Machine Tools
Sanderson Brothers and Newbould Ltd., Sheffield.
Magnetic Separators, Clutches, Chucks, and Lifting Magnets.
Electromagnets, Ltd., 48, High Street, Erdington, Birmingham.
Motors (Electric)
Metropolitan-Vickers, Ltd., Trafford Park, Manchester.
Naval Brass Ingots
McKechnie Bros. Ltd., Rotton Park St., Birmingham.
Non-Ferrous Alloys
Clifford, Chas. and Son, Ltd., Birmingham
Manganese Bronze and Brass Co. Ltd., Handford Works, Ipswich
McKechnie Bros., Ltd., Rotton Park St., Birmingham.
High Duty Alloys, Ltd., Trading Estate, Slough.
I.C.I. Metals Ltd., Kynoch Works, Witton, Birmingham, 6.
Non-Ferrous Metals
Reynolds Tube Co., Tyseley, Birmingham.
I.C.I. Metals Ltd., Kynoch Works, Witton, Birmingham, 6
McKechnie Bros. Ltd., Rotton Park St., Birmingham.
Pig Iron
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furnace.
Bradley & Foster, Ltd., Darlaston.
Presses
Eumuco Ltd., Beverley Works, Willow Ave, Barnes, London, S.W. 13.
Schloemann, A.-G., Dusseldorf, Germany.
Protection of Metal Parts for Use at High Temperatures.
Calorizing Corporation of Great Britain, Ltd., 32, Farringdon St., London, E.C. 4.
Pulverised Fuel Equipment
Alfred Herbert Ltd., Coventry.
Pyrometers
Electroflo Meters Ltd., Abbey Road, Park Royal, London, N.W. 1.
Ether, Ltd., Tyburn Road, Birmingham.
Honeywell Brown, Ltd., 70, St. Thomas Street, London.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham.
Recording Instruments
Dine Engineering Co. 60, Mount Street, Nechells, Birmingham.
Electroflo-Meters Co., Ltd., Abbey Road, Park Royal, London, N.W. 10.
Ether, Ltd., Tyburn Road. Birmingham.
George Kent Ltd., Luton, Beds.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
Metalectric Furnaces Ltd., Cornwall Rd., Smethwick, Birmingham
Refractories
Carborundum Co., Ltd., Trafford Park, Manchester.
J. and J. Dyson, Ltd., Stannington, Sheffield.
Kingscliffe Insulating Products, Ltd., Sheffield.
Thos. Marshall and Co., Loxley, near Sheffield
John G. Stein & Co., Bonnybridge, Scotland.
Roll Grinding Machines
Craven Bros. Ltd., Reddish. Stockport.
Roll Manufacturers
Tennent Ltd., Whifflet Foundry, Coatbridge, Scotland.
Rolling Mills
Demag, A. G., Germany.
Ehrhardt and Sehmer, Saarbrücken.
Fried. Krupp Grusonwerk A.-G. Magdeburg, Germany. Sole Agents in Great Britain: J. Rolland and Co., 2 Victoria Street, London, S.W. 1.
Lamberton and Co., Coatbridge.
Rheinische Walzmachinenfabrik, Germany.
Robertson, W. H. A., and Co., Ltd., Bedford.
August Schmitz, A.G., Germany.
Karl., Fr. Ungerer., Germany.
Silver Solder
Chas. Harrold & Co. Ltd., 283, St. Paul's Square, Birmingham.
Steels
Barrow Hæmatite, Steel Co., Ltd., Barrow-in-Furnace.

Continued in next column.

Edgar Allen & Co., Ltd., Imperial Steel Works, Sheffield.
Daniel Doncaster & Sons, Ltd., Sheffield.
Dunford & Elliott, Ltd., Sheffield.
English Steel Corporation Ltd., Sheffield.
Sanderson Bros. and Newbould, Ltd., Sheffield
United Steel Companies, Ltd., Sheffield.
Steel Sections
Barrow Hæmatite Steel Co., Ltd., Barrow-in-Furnace.
Steel Tubes aud Sections
Reynolds Tube Co., Tyseley, Birmingham.
Steelworks Plant
Wellman Smith Owen Engineering Corporation, Ltd., Victoria Station House, London, S.W. 1.
Temperature Controllers
Electroflo-Meters Co. Ltd., Abbey Road, Park Royal, London.
Ether, Ltd., Tyburn Road, Birmingham.
Honeywell Brown, Ltd., 70, St. Thomas Street, London, S.E.1.
Integra Co., Ltd., 183, Broad St., Birmingham, 15.
George Kent, Ltd., Luton.
Testing Machines
Howden, T. C., and Co., 517. Fleet Street, Birmingham.
Vitreosil Combustion Tube
Thermal Syndicate, Ltd., Wallsend-on-Tyne.

Index to Advertisers.

Printed for the Proprietors, The Kennedy Press, Limited, 21, Albion Street, Gaythorn, Manchester, by Percy Brothers (1937), Limited, Hotspur Press, Manchester and London.